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ABSTRACT

This welding curriculum guide treats two topics in detail: the care of tungsten electrodes and the entire concept of contamination control and the hafnium electrode and its importance in dual-air cutting systems that use compressed shop air for plasma arc cutting activities. The guide contains three units of instruction that cover the following topics: orientation and safety; equipment, applications, and techniques; and plasma arc cutting. Each instructional unit includes some or all of the following basic components of a unit of instruction: objective sheet, suggested activities, answers to assignment sheets, answers to written test, written test, unit evaluation form, teacher supplements, transparency masters, information sheet, student supplements, assignment sheets, and job sheets. A glossary of technical terms is also included. The unit components focus on measurable and observable learning outcomes and are designed for use in more than one lesson or class period. This teacher edition also contains the following information: use of the publication; tools, materials, and equipment list; competency profile; instructional/task analysis; academic and workplace skill classifications and definitions; related academic and workplace skills list; and reference list. (KC)

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Gas Tungsten Arc Welding and Plasma Arc Cutting

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GTAW and plasma arc safety •
Equipment, applications, and techniques •
GTAW job sheets for basic joints in all positions •
Job sheets for plasma arc cutting •

Teacher Edition

CE062-874

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MAVCC

Gas Tungsten Arc Welding and Plasma Arc Cutting

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Gas Tungsten Arc Welding and Plasma Arc Cutting

Teacher Edition

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Foreword

Gas Tungsten Arc Welding and Plasma Arc Cutting complement the MAVCC welding series with two more areas that will enhance welding students employability skills.

The care and feeding of tungsten electrodes and the entire concept of contamination control are treated in detail in the GTAW section of the text. The Plasma Arc Cutting section of the book introduces the hafnium electrode and its importance in dual-air cutting systems that use compressed shop air for PAC activities. The text is state-of-the-art, and will be a valuable addition to any welding program.

With MAVCC's format, introductory materials include a competency profile, instructional/task analysis, tools and equipment list, reference materials, and a summary of academic and workplace skills reinforced in the publication.

Special attention should be given to the teacher suggestions in each unit of instruction. These suggestions present ways to increase reinforcement of academic and workplace basic skills. Be reinforcing basic skills, the teacher will assist students in improving their employability skills.

As you use these instructional materials, we hope you will find they contribute to the quality of your program. We feel you will appreciate the technical changes in this edition and the streamlined format in which it is presented. Every effort has been made to make these materials readable and by all means useable. You as a teacher, will need to develop instructional strategies for localizing, individualizing, and supplementing the text, and motivating the students who work with these instructional material. As always, MAVCC appreciates hearing from users of our publications. Please write or call MAVCC and share what you like about *Gas Tungsten Arc Welding and Plasma Arc Cutting* and/or what you think needs to be changed.

Mervin Birdwell, Chairman
Board of Directors
Mid-America Vocational
Curriculum Consortium

Jim Steward
Executive Director
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Curriculum Consortium

Acknowledgements

The contents of this publication reflect the input of a planning and validation committee that met to help revise and expand the Mid-America Vocational Curriculum Consortium welding series. For their special help with *Gas Tungsten Arc Welding and Plasma Arc Cutting*, we extend a thank you to:

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Dave Roberts	Sales Manager, Majestic Metals, Denver, Colorado
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Joe Don Davidson	President, Oklahoma Joe's, Perry, Oklahoma
James Buhler	Head, Welding Department, Lake Area Vo-Tech Institute, Watertown, South Dakota

Additional thanks go to the manufacturers and suppliers whose procedures and graphic materials have enhance this text. A special thank you to the American Welding Society for their materials and assistance.

And finally to the Oklahoma Department of Vocational and Technical Education, a thank you to personnel in wordprocessing, art, and the print shop for their help in developing and printing a fine text.

Use of Introductory Materials

Introductory materials are included in the teacher guide only and contain useful information to assist administrators and teachers in planning for instruction.

In addition to the general information such as the table of contents, foreword, and acknowledgements page, information is included on the following:

1. **Use of this publication**—Explains the components of a unit of instruction and how they should be used as part of the teaching/ learning process.

2. **Competency profile**—Provides a record of student performance for each task included in a unit of instruction. This becomes a part of the student's permanent records and should be utilized when directing the student toward employment opportunities.

3. **Instructional/task analysis**—Provides a quick review of contents of the publication; identifies cognitive (knowledge) skills and psychomotor (doing) skills addressed in each unit of instruction.

4. **Related academic and workplace skills list**—Classifies unit tasks (assignment sheets and job sheets) according to related academic and workplace skills being reinforced. Skill areas reflected by skill groups, sub skills, and descriptions have been identified using *Workplace Basics: The Skills Employers Want*, developed by the American Society for Training and Development (ASTD) and the U.S. Department of Labor and adapted by MAVCC.

5. **Tools, equipment, and materials list**—Provides a comprehensive list of those items needed to successfully complete the assignment sheets and/or job sheets; assists administrator/teacher in determining program costs.

6. **Reference list**—Provides a comprehensive list of resources used in the development of this publication.

A glossary of terms may also be provided in the introductory materials depending on subject matter and committee recommendations.

As you use these materials, it is hoped that they will provide useful information to meet a variety of needs.

Use of This Publication

Instructional units

Gas Tungsten Arc Welding and Plasma Arc Cutting contains 3 units of instruction. Each instructional unit in a teacher guide includes some or all of the following basic components of a unit of instruction: objective sheet, suggested activities for the teacher, answers to assignment sheets, answers to written test, written test, unit evaluation form, teacher supplements, transparency masters, information sheet, assignment sheets, student supplements, and job sheets.

All of the unit components focus on measurable and observable learning outcomes. Teachers are encouraged to supplement, personalize, localize, and motivate with these materials in order to develop a complete teaching/learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the teacher will help to determine the following:

- Amount of materials that can be covered in each class period.
- Skills that must be demonstrated.
- Amount of class time needed for demonstrations.
- Amount of time needed for student practice.
- Supplementary materials, including print and nonprint media and equipment and supplies, that must be ordered.
- Resource people who must be contacted.

Objective sheet (Color code: White)

Each unit of instruction is based on performance objectives which state the goals for successful completion of the course. These performance objectives are stated in two forms: unit objectives which state the expected performance of each student after completion of the unit of instruction, and specific objectives which state what the student must do to reach the unit objective.

The objectives should be provided for students and stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods. Teachers should prepare for each unit by deciding how each objective can best be taught.

Teachers should feel free to modify, delete, or add objectives in order to meet the needs of the students and community. When objectives are added, the teacher should remember to supply the needed information, assignment and/or job sheets, and criterion test items.

Suggested activities (Color code: Pink)

This component is included only in the teacher guide. The suggested activities assist teachers during the preparation stage of the teaching/learning process by providing an instructional plan, teaching suggestions, and a list of supplemental resources. Ways to integrate academic and workplace skills have been included in the teacher suggestions, and skill areas have been noted in bold. (A table of academic and workplace skills with accompanying definitions has been provided on page xv.) The teacher should read the suggested activities before teaching the units and decide how each objective can best be taught. Time should also be allowed to obtain supplemental materials, prepare audiovisual materials, and contact outside resources. Duties of the teacher will vary according to the particular unit.

References used in the development of each unit are listed in the suggested-activities section, along with suggested supplemental resources that may be used to teach the unit. These materials can be used by the teacher to supplement her or his knowledge of the subject area or to help students with particular interests or objectives in the area covered.

Instructions for evaluating student performance on the job sheets are also included in the suggested-activities section. Teachers should select and discuss with students the rating scale that will be used.

Assignment and written test answers (Color code: Pink)

Assignment-sheet answers and written-test answers are designed to assist the teacher in evaluation of student performances.

Written test (Color code: Yellow)

This component provides criterion-referenced evaluation of every cognitive objective listed in the unit of instruction. The test appears in the teacher guide only, but duplication is permitted for student use. If objectives have been added, deleted, or modified, appropriate changes should be made on the written test. It is recommended that the tests be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of test items from the units covered may be used for final tests at the end of each term if desired.

Unit evaluation form (Color code: White)

This sheet provides teachers with a record of each students performance on a unit of instruction. It includes space for assignment sheet ratings, job sheet ratings, written test scores, and teacher comments. The unit evaluation form is included in the teacher guide only, but may be duplicated.

Teacher supplements (Color code: White)

This component is included only in the teacher guide. Teacher supplements are optional materials for the teacher to use. They have three purposes: to provide the teacher with higher level materials to stretch the advanced student, with remedial information or practice to assist the less-advanced student, and with state-of-the-art information in which the teacher may not have background or with information that is not readily available in other books. Some teacher supplements may be duplicated for student use and are marked accordingly.

Transparency masters (Color code: White)

Transparencies are included in the teacher guide only and are used to direct the students' attention to the topic of discussion. They may provide illustrations, charts, schematics, or additional information needed to clarify and reinforce objectives included in the unit of instruction.

Information sheet (Color code: Green)

The information sheet provides the content essential for meeting the cognitive (knowledge) objectives of the unit. Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. Students should read the information sheet before the information is discussed in class. Space is provided in margins for students and teachers to add notes that supplement, localize, personalize, or provide information for the teaching of each objective.

Student supplements (Color code: White)

Student supplements are included in the student manual. The information presented in a student supplement may consist of tables, charts, written information, forms, or other information students will need in order to complete one or more of the assignment and/or job sheets. Students are not directly tested over the information presented in a supplement; however, their ability to apply this information may be evaluated in the completion of assignment sheets or job sheets.

Assignment sheets (Color code: Tan)

Assignment sheets provide students with pencil and paper activities that give students the opportunity to make practical application of the knowledge in the information sheet. Criteria are provided to objectively evaluate student performance.

Job sheets (Color code: Blue)

The job sheets provide criteria to objectively evaluate student performance, a list of required equipment and materials, and a step-by-step procedure for performing a psychomotor skill. The teacher should discuss the equipment and materials available in the classroom and/or laboratory and demonstrate the procedure prior to having students practice procedure. When a student is ready to be evaluated, the teacher should follow instructions for evaluating student performance which may be found in the teacher guide.

Job sheets are an important segment of each unit. Job sheets provide potential employers with a picture of the skills being taught during training and the performances that might reasonably be expected from an individual who has had this training.

Disseminating material

Material may be given out a unit or page at a time to keep the material before the student always new. Some teachers ask students to furnish a three-ring binder or folder for the current unit of study. This is convenient for students taking the material home to study. Upon completion, each unit is then placed in a larger binder. Some teachers prefer to store the material by unit in filing cabinets or boxes until needed.

For best results, provide student materials for each student. Student manuals contain objective sheets, information sheets, student supplements, assignment sheets, and job sheets. Students should be allowed to take their materials home at the end of the course.

Academic and Workplace Skills
(Classifications and Definitions)

Skill Groups	Sub Skills	Definitions
Learning Skills	Learning to learn	Developing ability to apply knowledge to other situations; knowing how to learn.
Foundation Skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
	Writing	Communicating a thought, idea or fact in written form in a clear, concise manner.
	Math	Applying computation skills such as reasoning, estimation, and problem solving as they are actually used on the job.
	Science	Applying knowledge learned through study or practice that is based on scientific principles as they relate to specific tasks.
Communication Skills	Listening	Listening for content, conversation, long-term contexts, emotional meaning, and directions.
	Oral communication	Communicating a thought, idea, or fact in spoken form in a clear, concise manner.
Adaptability Skills	Creative thinking	Using imagination to create something new—i.e. an idea, invention, work of art.
	Problem solving (critical thinking)	Recognizing and defining problems, inventing, and implementing solutions, and tracking and evaluating results.
Personal Management Skills	Self-esteem	Developing self-confidence and creating a positive self-image.
	Motivation/goal setting	Setting and meeting defined goals and objectives.
	Personal and career development	Emphasizing self-direction by establishing and implementing a plan.
Group Effectiveness Skills	Interpersonal relations	Developing ability to maintain positive relations with others.
	Negotiation	Resolving conflict between two or more individuals.
	Teamwork	Working together in a group to reach a common goal.
Influence Skills	Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Leadership	Directing/influencing group in performance of a specific task; accepting responsibility for others.

Gas Tungsten Arc Welding and Plasma Arc Cutting

Competency Profile

Name: _____

Directions: Evaluate the student using the rating scale below. Write the appropriate number to indicate the degree of competency achieved. The descriptions associated with each of the numbers focused on a level of student performance for each of the tasks listed. The written test scoreline is provided for optional teacher use. It may not be applicable in all cases.

Option A

Rating scale:
- 4 - Skilled - Can perform job with no additional training.
- 3 - Moderately Skilled - Has performed job during training program; limited additional training may be required.
- 2 - Limited Skill - Has performed job during training program; additional training is required to develop skill.
- 1 - Unskilled - Is familiar with process, but is unable to perform job.
- 0 - No Exposure - No information or practice provided during training program, complete training required.
- NA - Non-applicable.

Option B

Yes - Can perform with no additional training
No - Is unable to perform satisfactorily

Unit 1: GTAW Orientation and Safety

_____1. Solve problems concerning GTAW safety.
_____2. _____

_____Written Test Score

Unit 2: GTAW Equipment, Applications, and Techniques

_____1. Set up a flow meter regulator for GTAW shielding gases.
_____2. Set up and shut down GTAW equipment for welding mild or stainless steel.
_____3. Prepare mild or stainless steel for GTAW.
_____4. Prepare a tungsten electrode for welding mild or stainless steel.
_____5. Strike and maintain an arc to make stringer beads on mild or stainless steel without filler metal in the flat position.
_____6. Strike and maintain an arc to make stringer beads on mild or stainless steel with filler metal in the flat position.
_____7. Weld to specifications a fillet weld lap joint on mild or stainless steel in the flat position.
_____8. Weld to specifications a fillet weld T-joint on mild or stainless steel in the flat position.
_____9. Weld to specifications an open-root square-groove butt joint on mild or stainless steel in the flat position.

_____10. Weld to specifications a fillet weld lap joint on mild or stainless steel in the horizontal position.
_____11. Weld to specifications a fillet weld T-joint on mild or stainless steel in the horizontal position.
_____12. Weld to specifications a fillet weld lap joint on mild or stainless steel in the vertical position.
_____13. Weld to specifications a fillet weld T-joint on mild or stainless steel in the vertical position.
_____14. Weld to specifications an open-root square-groove butt joint on mild or stainless steel in the vertical position.
_____15. Weld to specifications a fillet weld lap joint on mild or stainless steel in the overhead position.
_____16. Weld to specifications a fillet weld T-joint on mild or stainless steel in the overhead position.
_____17. Set up and shut down GTAW equipment for welding aluminum.
_____18. Prepare aluminum for GTAW.
_____19. Prepare a tungsten electrode for welding aluminum.
_____20. Strike and maintain an arc to make stringer beads on aluminum without filler metal in the flat position.
_____21. Strike and maintain an arc to make stringer beads on aluminum with filler metal in the flat position.
_____22. Weld to specifications a fillet weld lap joint on aluminum in the flat position.
_____23. Weld to specifications a fillet weld T-joint on aluminum in the flat position.
_____24. Weld to specifications a square-groove butt joint on aluminum in the flat position.
_____25. Weld to specifications a fillet weld lap joint on aluminum in the horizontal position.
_____26. Weld to specifications a fillet weld T-joint on aluminum in the horizontal position.
_____27. Weld to specifications a fillet weld lap joint on aluminum in the vertical position.
_____28. Weld to specifications a fillet weld T-joint on aluminum in the vertical position.
_____29. Weld to specifications a square-groove butt joint on aluminum in the vertical position.
_____30. Weld to specifications a fillet weld lap joint on aluminum in the overhead position.
_____31. Weld to specifications a fillet weld T-joint on aluminum in the overhead position.
_____32. _____

_____Written Test Score

Unit 3: Plasma Arc Cutting

_____1. Prepare a PAC machine for operation.
_____2. Complete a contact cut on selected metal.
_____3. Complete a stand-off cut on selected metal.
_____4. Gouge mild steel plate with a PAC unit.

_____5. _____

_____Written Test Score

COMMENTS: _____

_____

_____

_____

_____

Evaluator: _____ Date: _____

*** Permission to duplicate this profile is granted.**

Instructional/Task Analysis

Related Information: What the Student Should Know	Application: What the Student Should Be Able to Do
Unit 1: GTAW Orientation and Safety	
1. Terms and definitions.	16. Solve problems concerning GTAW safety. (Assignment Sheet 1)
2. Advantages of GTAW.	
3. Limitations of GTAW.	
4. Principles of GTAW.	
5. GTAW applications.	
6. Benefits from learning GTAW.	
7. Electrical safety guidelines for GTAW.	
8. Guidelines for duty cycle safety.	
9. Rules for handling welding cables and gas and coolant hoses.	
10. Rules for handling hollow castings and containers.	
11. Hazards associated with arc rays.	
12. Types of welding hoods and their characteristics.	
13. Selecting a safe lens shade for GTAW.	
14. Clothing requirements for arc welding.	
15. Environmental safety requirements.	

Related Information: What the Student Should Know	Application: What the Student Should Be Able to Do
Unit 2: GTAW Equipment, Applications, and Techniques	
1. Terms and definitions.	
2. GTAW machine controls with their functions.	
3. The concept of pulse current and its use in GTAW.	
4. Types of GTAW systems.	
5. Cooling system safety.	
6. Types of power cables and their characteristics.	
7. Parts of a GTAW torch.	
8. Gas lens and its uses.	
9. Types of nozzles and their functions.	
10. Steps in GTAW nozzle selection.	
11. GTAW shielding gases and their characteristics.	
12. Flow meter design and use.	
13. Flow rates for GTAW shielding gases.	
14. Tungsten electrodes, their characteristics and applications.	
15. Guidelines for preparing tungsten electrodes for DC welding.	
16. Guidelines for grinding electrodes for DC welding.	
17. Guidelines for preparing electrodes for AC welding.	
18. Guidelines for GTAW electrode extension.	

Related Information: What the Student Should Know

19. Guidelines for filler metal selection and use.

20. Requirements for base metal preparation.

21. Special problems with contamination and air movement.

22. Steps in manual welding with a filler rod.

23. Backup bars and their uses in GTAW.

24. Guidelines for troubleshooting GTAW problems.

Application: What the Student Should Be Able to Do

25. Set up a flow meter regulator for GTAW shielding gases. (Job Sheet 1)

26. Set up and shut down GTAW equipment for welding mild or stainless steel. (Job Sheet 2)

27. Prepare mild or stainless steel for GTAW. (Job Sheet 3)

28. Prepare a tungsten electrode for welding mild or stainless steel. (Job Sheet 4)

29. Strike and maintain an arc to make stringer beads on mild or stainless steel without filler metal in the flat position. (Job Sheet 5)

30. Strike and maintain an arc to make stringer beads on mild or stainless steel with filler metal in the flat position. (Job Sheet 6)

31. Weld to specifications a fillet weld lap joint on mild or stainless steel in the flat position. (Job Sheet 7)

32. Weld to specifications a fillet weld T-joint on mild or stainless steel in the flat position. (Job Sheet 8)

33. Weld to specifications an open-root square-groove butt joint on mild or stainless steel in the flat position. (Job Sheet 9)

34. Weld to specifications a fillet weld lap joint on mild or stainless steel in the horizontal position. (Job Sheet 10)

35. Weld to specifications a fillet weld T-joint on mild or stainless steel in the horizontal position. (Job Sheet 11)

Related Information: What the Student Should Know	Application: What the Student Should Be Able to Do
	36. Weld to specifications a fillet weld lap joint on mild or stainless steel in the vertical position. (Job Sheet 12)
	37. Weld to specifications a fillet weld T-joint on mild or stainless steel in the vertical position. (Job Sheet 13)
	38. Weld to specifications an open-root square-groove butt joint on mild or stainless steel in the vertical position. (Job Sheet 14)
	39. Weld to specifications a fillet weld lap joint on mild or stainless steel in the overhead position. (Job Sheet 15)
	40. Weld to specifications a fillet weld T-joint on mild or stainless steel in the overhead position. (Job Sheet 16)
	41. Set up and shut down GTAW equipment for welding aluminum. (Job Sheet 17)
	42. Prepare aluminum for GTAW. (Job Sheet 18)
	43. Prepare a tungsten electrode for welding aluminum. (Job Sheet 19)
	44. Strike and maintain an arc to make stringer beads on aluminum without filler metal in the flat position. (Job Sheet 20)
	45. Strike and maintain an arc to make stringer beads on aluminum with filler metal in the flat position. (Job Sheet 21)
	46. Weld to specifications a fillet weld lap joint on aluminum in the flat position. (Job Sheet 22)

Related Information: What the Student Should Know	Application: What the Student Should Be Able to Do
	47. Weld to specifications a fillet weld T-joint on aluminum in the flat position. (Job Sheet 23)
	48. Weld to specifications a square-groove butt joint on aluminum in the flat position. (Job Sheet 24)
	49. Weld to specifications a fillet weld lap joint on aluminum in the horizontal position. (Job Sheet 25)
	50. Weld to specifications a fillet weld T-joint on aluminum in the horizontal position. (Job Sheet 26)
	51. Weld to specifications a fillet weld lap joint on aluminum in the vertical position. (Job Sheet 27)
	52. Weld to specifications a fillet weld T-joint on aluminum in the vertical position. (Job Sheet 28)
	53. Weld to specifications a square-groove butt joint on aluminum in the vertical position. (Job Sheet 29)
	54. Weld to specifications a fillet weld lap joint on aluminum in the overhead position. (Job Sheet 30)
	55. Weld to specifications a fillet weld T-joint on aluminum in the overhead position. (Job Sheet 31)

Unit 3: Plasma Arc Cutting

1. Terms and definitions.	
2. Basic characteristics of plasma arc cutting.	
3. Basic components and their functions in an air cut PAC system.	

Related Information: What the Student Should Know

4. Plasma arc electrical safety.
5. Plasma arc environmental safety.
6. Plasma arc workplace safety.
7. Advantages of plasma arc cutting.
8. Characteristics of plasma arc transfer modes.
9. Guidelines for PAC electrode selection.
10. Guidelines for cutting nozzle selection and installation.
11. Shielding cups, their design and uses.
12. Plasma air and secondary air used with PAC.
13. PAC consumables, their characteristics and maintenance.
14. PAC system duty cycles.
15. Guidelines for setting PAC flow rate and flow pressure.
16. Guidelines for using compressed air with a PAC system.
17. Factors affecting cutting speeds.
18. Techniques for contact and stand-off cutting.
19. Techniques for cutting expanded metal.
20. Techniques for gouging metal.
21. Techniques for piercing and beveling metal.
22. Cutting faults and their probable causes.

Application: What the Student Should Be Able to Do

23. Prepare a PAC machine for operation. (Job Sheet 1)
24. Complete a contact cut on selected metal. (Job Sheet 2)
25. Complete a stand-off cut on selected metal. (Job Sheet 3)
26. Gouge mild steel plate with a PAC unit. (Job Sheet 4)

Related Academic and Workplace Skills
For *Gas Tungsten Arc Welding and Plasma Arc Cutting*

Task	Skill Group	Sub Skill	Description
Unit 1: GTAW Orientation and Safety			
Solve problems concerning GTAW safety.	Foundation Skills	Reading	Analyzes written information
	Adaptability Skills	Problem Solving (Critical Thinking)	Recognizes problems and creates effective solutions for them
Unit 2: GTAW Equipment, Applications, and Techniques			
Set up a flow meter regulator for GTAW shielding gases. (J.S. 1)	Foundation Skills	Reading	Comprehends written information and applies it to a task
		Science	Applies knowledge learned through practice to set up a flow meter
Set up and shut down GTAW equipment for welding mild or stainless steel. (J.S. 2)	Foundation Skills	Reading	Comprehends written information and applies it to a task
		Science	Applies knowledge learned through practice to make critical machine adjustments
Prepare mild or stainless steel for GTAW. (J.S. 3)	Foundation Skills	Reading	Comprehends and follows written information
		Science	Manipulates hand and powered tools to complete a cleaning process
Prepare a tungsten electrode for welding mild or stainless steel. (J.S. 4)	Foundation Skills	Reading	Comprehends and follows written information
		Science	Manipulates hand and powered tools to prepare an electrode
Strike and maintain an arc to make stringer beads on mild or stainless steel without filler metal in the flat position. (J.S. 5)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to apply stringer beads without filler metal
Strike and maintain an arc to make stringer beads on mild or stainless steel with filler metal in the flat position. (J.S. 6)	Foundation Skills	Reading	Comprehends and follows written instructions

Task	Skill Group	Sub Skill	Description
		Science	Adapts welding skills to apply stringer beads with filler metal
Weld to specifications a fillet weld lap joint on mild or stainless steel in the flat position. (J.S. 7)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to complete a fillet weld on a lap joint in the flat position
Weld to specifications a fillet weld T-joint on mild or stainless steel in the flat position. (J.S. 8)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to make a fillet weld on a T-joint in the flat position
Weld to specifications an open-root square-groove butt joint on mild or stainless steel in the flat position. (J.S. 9)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to make a square-groove butt joint weld in the flat position
Weld to specifications a fillet weld lap joint on mild or stainless steel in the horizontal position. (J.S. 10)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to make a fillet weld on a lap joint in the horizontal position
Weld to specifications a fillet weld T-joint on mild or stainless steel in the horizontal position. (J.S. 11)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to make a fillet weld on a T-joint in the horizontal position
Weld to specifications a fillet weld lap joint on mild or stainless steel in the vertical position. (J.S. 12)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to make a fillet weld on a lap joint in the vertical position
Weld to specifications a fillet weld T-joint on mild or stainless steel in the vertical position. (J.S. 13)	Foundation Skills	Reading	Comprehends and follows written instructions

Task	Skill Group	Sub Skill	Description
		Science	Adapts welding skills to complete a fillet weld on a T-joint in the vertical position
Weld to specifications an open-root square-groove butt joint on mild or stainless steel in the vertical position. (J.S. 14)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to complete a square-groove butt joint in the vertical position
Weld to specifications a fillet weld lap joint on mild or stainless steel in the overhead position. (J.S. 15)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to complete a fillet weld in the overhead position
Weld to specifications a fillet weld T-joint on mild or stainless steel in the overhead position. (J.S. 16)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to complete a fillet weld in the overhead position
Set up and shut down GTAW equipment for welding aluminum. (J.S. 17)	Foundation Skills	Reading	Comprehends written information and applies it to a task
		Science	Applies knowledge learned in training to set up and adjust equipment
Prepare aluminum for GTAW. (J.S. 18)	Foundation Skills	Reading	Comprehends written information and applies it to a task
		Science	Manipulates hand and powered tools to complete a cleaning process
Prepare a tungsten electrode for welding aluminum. (J.S. 19)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Uses power tools to prepare a special electrode
Strike and maintain an arc to make stringer beads on aluminum without filler metal in the flat position. (J.S. 20)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to apply stringer beads without filler metal

Task	Skill Group	Sub Skill	Description
Strike and maintain an arc to make stringer beads on aluminum with filler metal in the flat position. (J.S. 21)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to apply stringer beads with filler metal
Weld to specifications a fillet weld lap joint on aluminum in the flat position. (J.S. 22)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to make a fillet weld on a lap joint in the flat position
Weld to specifications a fillet weld T-joint on aluminum in the flat position. (J.S. 23)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to make a fillet weld on a T-joint in the flat position
Weld to specifications a square-groove butt joint on aluminum in the flat position. (J.S. 24)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to weld a square-groove butt joint in the flat position
Weld to specifications a fillet weld lap joint on aluminum in the horizontal position. (J.S. 25)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to weld a lap joint in the horizontal position
Weld to specifications a fillet weld T-joint on aluminum in the horizontal position. (J.S. 26)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to weld a fillet weld T-joint in the horizontal position
Weld to specifications a fillet weld lap joint on aluminum in the vertical position. (J.S. 27)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to weld a lap joint in the vertical position
Weld to specifications a fillet weld T-joint on aluminum in the vertical position. (J.S. 28)	Foundation Skills	Reading	Comprehends and follows written instructions

Task	Skill Group	Sub Skill	Description
		Science	Adapts welding skills to weld a fillet weld T-joint in the vertical position
Weld to specifications a square-groove butt joint on aluminum in the vertical position. (J.S. 29)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to weld a square-groove butt joint in the vertical position
Weld to specifications a fillet weld lap joint on aluminum in the overhead position. (J.S. 30)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to weld a lap joint in the overhead position
Weld to specifications a fillet weld T-joint on aluminum in the overhead position. (J.S. 31)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts welding skills to weld a fillet weld T-joint in the overhead position
Unit 3: Plasma Arc Cutting			
Prepare a PAC machine for operation. (J.S. 1)	Foundation Skills	Reading	Comprehends written information and applies it to a task
		Science	Applies knowledge learned through practice to set up and adjust equipment
Complete a contact cut on selected metal. (J.S. 2)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts cutting skills to complete a contact cut
Complete a stand-off cut on selected metal. (J.S. 3)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts cutting skills to complete a stand-off cut
Gouge mild steel plate with a PAC unit. (J.S. 4)	Foundation Skills	Reading	Comprehends and follows written instructions
		Science	Adapts cutting skills to gouge mild steel plate

Tools, Equipment, and Materials List

For GTAW:

Adjustable wrench
Air cooled GTAW torch and cables
Aluminum plate
Argon shielding gas
Bevel square
C-clamps
Clean shop rags
Cleaner/deoxidizer solution
Fine grit grinding wheel (minimum 120-grit)
Flowmeter
Gap wire (1/16" and 3/32")
GTAW machine
GTAW machine accessories (preferred):
- High frequency spark control
- High frequency spark intensity rheostat
- Pulse mode setting
- Remote control switch (foot or hand)
- Soft-start switch

GTAW torch parts (for both demonstration and use):
- Assorted cups (ceramic, fused quartz, metal, or alumina)
- Cap
- Collet
- Torch body

Helium shielding gas
Mild steel plate
Open-end Wrench (1⅛")
Pedestal grinder
Personal safety clothing for each student
Pliers
Portable grinder and sanding attachment
Safety glasses and face shields
Selected filler metal rods
Soapstone
Stainless steel brush
Stainless steel plate
Tungsten electrodes:
- 1% thoriated
- 2% thoriated
- Pure
- Zirconiated

Water cooled GTAW torch and cables
Wire brush

For PAC:

Dual-air PAC machine
Ear plugs or protective muffs
PAC machine accessories
- Attached or in-line filter
- Component tools
- Compressed air supply
- P.S.I. gauge

PAC torch and accessories
- Gouging nozzle
- Nozzle assortment/cutting
- Regular gas cup or device
- Replacement hafnium electrodes
- Stand-off gas cup or device

References

A History of Plasma Cutting Milestones in the Development of a New Technology. Hanover, NH: Hypertherm, Inc., 1991.

Connor, Leonard P., ed. *Welding Handbook Eighth Edition, Vol. 1, Welding Technology.* Miami, FL: American Welding Society, 1987.

Fortney, Clarence and Mike Gregory. *Gas Tungsten Arc Welding.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1984.

Instruction Manual for the Thermal Arc® PAK® 5XR™. St. Louis, MO: Thermal Dynamics Corporation, 1987.

New Lessons in Arc Welding. Cleveland, OH: The Lincoln Electric Company, 1981.

1988/98 Welding & Fabrication Data Handbook. Cleveland, OH: Penton Publishing, Inc., 1988.

O'Brien, R. L., ed. *Welding Handbook Eighth Edition, Vol. 2, Welding Processes.* Miami, FL: American Welding Society, 1991.

Smith Plasma Cutting Systems Owners Manual for SPC50A, SPC80A, and SPC120A-4. Watertown, SD: Smith Equipment, Division of Tescom Corporation, undated.

The Procedure Handbook of Arc Welding, Twelfth Edition. Cleveland, OH: The Lincoln Electric Company, 1973.

GTAW Orientation and Safety Unit 1

Objective Sheet

Unit Objective

After completing this unit, the student should be able to discuss safety requirements for gas tungsten arc welding and solve problems concerning GTAW safety. The student will demonstrate these competencies by completing the assignment Sheet and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to GTAW orientation and safety with their correct definitions.
2. Select true statements about advantages of GTAW.
3. Select true statements about limitations of GTAW.
4. Complete statements about principles of GTAW.
5. Complete statements about GTAW applications.
6. Complete statements about benefits from learning GTAW.
7. Select true statements about electrical safety guidelines for GTAW.
8. Solve problems about guidelines for duty cycle safety.
9. Select true statements about important rules for handling welding cables and gas and coolant hoses.
10. Select true statements about rules for handling hollow castings and containers.
11. Complete statements about hazards associated with arc rays.
12. Complete statements about types of welding hoods and their characteristics.
13. Solve problems about guidelines for selecting a safe lens shade for GTAW.
14. Solve problems about protective clothing requirements for arc welding.
15. Complete statements about environmental safety requirements.
16. Solve problems concerning GTAW safety. (Assignment Sheet 1)

GTAW Orientation and Safety
Unit 1

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for students with special needs.
4. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
10. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of the written test. Add or modify test items as needed.
13. Give written test.
14. Compile assignment sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignments.
15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Use Objectives 5 and 6 to point out to students the advantages of GTAW in industry and the advantages for students who become skilled in GTAW applications. **Personal and career development**, acquiring GTAW skills.

2. Discuss duty cycle safety in Objective 8 with special emphasis on the slower welding speeds associated with GTAW and the need for students to develop a new awareness of duty cycle and its importance to the GTAW process. **Learning to learn**, developing increased awareness of duty cycle.

3. Review general welding safety as you teach the final seven objectives in the unit. Stress lens shade selection and point out that lens shade selection for GTAW is different from that for SMAW, and why it is different. **Learning to learn**, applying eye safety in the workplace.

Resources Used in Developing This Unit

1. Connor, Leonard, Pl, ed. *Welding Handbook, Eighth Edition, Vol. 1, Welding Technology*. Miami, FL: American Welding Society, 1987.

2. O'Brien R. L., ed. *Welding Handbook, Eighth Edition, Vol. 2, Welding Processes*. Miami, FL: American Welding Society, 1991.

3. *1988/89 Welding & fabrication Data Handbook*. Cleveland, OH: Penton Publishing, Inc., 1988.

4. *The Procedure Handbook of Arc Welding, Twelfth Edition*. Cleveland, OH: The Lincoln Electric Company, 1973.

5. Fortney, Clarence, and Mike Gregory. *Gas Tungsten Arc Welding*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1984.

Suggested Supplemental Resources

1. Miller-093119—"The Gas Tungsten Arc Welding Process," a 25-minute production detailing set-up and operator techniques. Filmed with high-speed photography; also covers ways to control GTAW variables. Available in VHS format. Available from:

   Miller Electric Mfg. Co.
   P.O. Box 1079
   Appleton, WI 54912
   Phone: 414-734-9821

2. HOB-20—"GTAW" covers 28 topics in VHS and other formats including videocassette tapes with instructor's guide. Available from:

   Hobart Brothers Company
   600 West Main Street
   Troy, OH 45373
   Phone: 513-332-4000

3. ITC-8—"Principles of TIG" covers GTAW safety, equipment electrodes, gas, arc start, techniques, and shutdown. Videocassette. Available from:

   Industrial Training Corp.
   13515 Dulles Technology Drive
   Herdon, VA 22071-3416
   Phone: 800-638-3757 or 703-471-1414

4. KEN-4—"Gas Tungsten Arc Welding" is a welding program complete with student and instructor materials and equipment. Available in both Spanish and English from:

   Ken Cook Education Systems
   12855 West Silver Spring Drive
   P.O. Box 207
   Butler, WI 53007
   Phone: 216-481-4300

GTAW Orientation and Safety
Unit 1

Answers to Assignment Sheet 1

Note: Student answers should approximate those given.

1. Yes. Clean up water and dry the area, or cover the area with a suitable insulating material.

2. Yes. Put cables in a safe and proper place, never on a cylinder

3. Yes. Put a darker shade lens in the helmet or check for cracks in the lens seal.

4. Yes. Wear a face shield or a flip-type welding hood when grinding or sanding.

5. Yes. Check area for proper ventilation and have operator stand to one side of fumes.

GTAW Orientation and Safety
Unit 1

Answers to Written Test

1. a. 4 f. 1
   b. 6 g. 8
   c. 2 h. 3
   d. 10 i. 5
   e. 7 j. 9

2. a, b, c, e

3. a, b

4. a. Nonconsumable
   b. Gas
   c. Shielding gas

5. a. In all
   b. And thicknesses
   c. Heat
   d. Ferrous and nonferrous

6. a. Nonconsumable, gases
   b. Eye-hand coordination
   c. Better jobs and higher pay

7. b, c, e, f, g, i

8. a. 2
   b. 3

9. a, c, d, f, g, h, i

10. a

11. a. Radiation
    b. Radiation, blister
    c. Shielded

12. a. Stationary, spring retainer
    b. Flip-front, plastic lens

13. a. 3
    b. 2

Answers to Written Test

14. a. 1
    b. 1
    c. 2

15. a. Toxic fumes
    b. Oxygen displacement
    c. Continuous
    d. Poor work

GTAW Orientation and Safety
Unit 1

Written Test

Name _____ Score _____

1. Match the terms on the right with their correct definitions.

_____a.	A gas supplied to the back side of a weldment to prevent atmospheric contamination during the root pass	1. Inert gas
_____b.	Elements in the atmosphere and/or impurities formed from chemical reactions between a base metal, filler metal, electrode, or shielding gas	2. Deposition rate
_____c.	The weight of filler metal placed onto a weld in a given period of time	3. Oxygen displacement
_____d.	An arc welding process that produces coalescence of metals by heating them with an arc between a nonconsumable tungsten electrode and a workpiece; shielding is obtained from a gas	4. Backup purge
_____e.	A brand name sometimes used to identify the gas tungsten arc welding process	5. Shielding gas
_____f.	A gas that normally does not combine chemically with a base metal or filler metal	6. Contaminants
_____g.	Material that does not melt or transfer to a weld	7. Heliarc
_____h.	The tendency of any arc or flame to reduce oxygen in the breathing zone around a welding activity	8. Nonconsumable
_____i.	Protective gas used to prevent atmospheric contamination during a welding procedure	9. Toxic hazards
_____j.	Poisonous gases, fumes, and vapors produced by chemical reactions in certain welding processes	10. Gas tungsten arc welding

2. Select true statements about advantages of GTAW. Place an "X" beside each true statement.

   _____a. GTAW uses no flux, produces no slag or spatter, and requires no after-weld cleaning.

   _____b. GTAW is excellent for the root pass on carbon and stainless steel pipe.

   _____c. The controlled heat concentration with GTAW reduces distortion and stress in base metals.

   _____d. The GTAW process is good for welding thick or bulky items in a variety of metals.

   _____e. With GTAW, the operator can clearly see the arc and weld puddle, and the operator has close control of current and the welding process.

3. Select true statements about limitations of GTAW. Place an "X" beside each true statement.

   _____a. GTAW will not function in a windy environment.

   _____b. Deposition rate with GTAW is low, compared to other processes.

   _____c. The faster welding speeds with GTAW increases production costs.

4. Complete statements about principles of GTAW. Circle the material that best completes each of the following statements.

   a. The heat needed for fusion is generated by an arc between a (**nonconsumable**) (**consumable**) tungsten electrode and a base metal.

   b. As heat is generated from the arc, a shielding (**flux**) (**gas**) surrounds the arc stream and the molten puddle formed by the arc and helps to stabilize the arc and protect the puddle from contaminants.

   c. Filler metal may be added with a filler rod inserted into the weld puddle where it is also protected by the (**shielding gas**) (**stabilizing flux**).

5. Complete statements about GTAW applications. Circle the material that best completes each of the following statements.

   a. With GTAW, welding is possible (**in flat, horizontal, and vertical**) (**in all**) positions.

   b. GTAW can be done on a wide range of metals (**and thicknesses**) (**and limited thicknesses**).

   c. GTAW is especially effective where precise (**heat**) (**deposition**) control is necessary for a quality weld such as in aircraft assembly or small, irregular shaped objects.

   d. GTAW is good to excellent for all aluminum applications, and especially good on other thin (**ferrous and nonferrous**) (**nonferrous**) metals.

6. Complete statements about benefits from learning GTAW. Circle the material that best completes each of the following statements.

   a. GTAW introduces a beginning welder to the concept of a (**nonconsumable**) (**consumable**) electrode and shielding (**gases**) (**fluxes**) and their uses.

   b. GTAW challenges the student to improve manipulative skills and(**eye-hand coordination**) (**welding know how**).

   c. Beginning welders may go to work in a place where there is no opportunity to learn GTAW, so learning GTAW early provides a beginner with an opportunity to achieve skills that will bring (**better jobs and high pay**) (**rapid advancement**).

7. Select true statements about electrical safety guidelines for GTAW. Place an "X" beside each true statement.

   _____a. All electrical equipment should have an earth ground for safety reasons, and this ground should be the same as the work lead to workpiece ground that completes the welding circuit.

   _____b. Keep electrical connections tight, clean, and dry because poor connections can heat up, cause bad welds, produce dangerous arcs and sparking, and even melt.

   _____c. Keep work area, equipment, and clothing dry because even a slight amount of moisture can conduct enough electricity to cause a severe shock.

   _____d. Never dip a torch in water to cool it, unless the torch is exceptionally hot.

_____e. Disconnect and lock out all electric power sources before doing any work on electrical equipment.

_____f. Keep welding cables as close to the work area as possible and do not connect cables to building framework because current can be directed through lifting chains and cables and weaken them.

_____g. When working in high places, carefully examine work area for electrical hazards because a shock in such conditions could cause a fall and severe injury.

_____h. When using a high frequency intensity control for GTAW, set the control at a maximum setting for the job activity to avoid getting interference from nearby communications equipment.

_____i. Make sure that all GTAW machines using high frequency controls have both input and output grounded to avoid erratic frequency interference.

8. Solve problems about guidelines for duty cycle safety. Circle the number of the statement that best solves each of the following problems.

   a. You are working with a GTAW machine that has a duty cycle of only 10 percent. You know to:

      (1) Increase amperage to accomplish more welding in a shorter time.

      (2) Pay careful attention to the actual time you spend welding.

      (3) Stop every ten minutes to let the machine cool.

   b. You are working with a GTAW machine that has a 20 percent duty cycle. You estimate the welding job will take at least 30 minutes. You know to:

      (1) Operate the machine 6 minutes and then allow it to cool for 6 minutes.

      (2) The duty cycle will cover the entire time span so just complete the weld and be done with it.

      (3) Operate the machine no more than 2 minutes out of each 10 minute period.

9. Select true statements about important rules for handling welding cables and gas and coolant hoses. Place an "X" beside each true statement.

   _____a. Never drag cables or hoses through dirt or oil, and never pull on a cable to force if over an obstruction.

   _____b. Use only solvent and rags to clean cables and hoses.

   _____c. When not in use, keep cables and hoses coiled free of kinks and properly stored.

   _____d. Never drape a welding cable over any type of gas cylinder, and NEVER strike an arc on a gas cylinder.

   _____e. Never interchange gas and water hoses without purging them first.

   _____f. Disconnect and remove electrode holders and cables used for SMAW.

   _____g. Keep cables off metal tables or any grounding surfaces.

   _____h. Make sure water-cooled systems have water turned off when shutting down.

   _____i. Use welding cable covers.

10. Select true statements about rules for handling hollow castings and containers. Place an "X" beside each true statement.

   _____a. Vent hollow castings or containers before heating, cutting, or welding on them.

   _____b. Do not heat, cut, or weld on tanks, drums, and sealed containers unless you know they're empty.

11. Complete statements about hazards associated with arc rays. Circle the material that best completes each of the following statements.

   a. A GTAW arc produces ultraviolet and infrared (**radiation**) (**light**) that can severely burn eyes that are unprotected with a proper shade of protective lens.

   b. (**Radiation**) (**Light**) from a GTAW arc is strong enough to sunburn or sometimes (**discomfort**) (**blister**) bare skin if the exposure is intense or for an extended period, so arms, legs, and torso should be covered with durable flame-resistant clothing.

   c. Work stations and work areas should be (**shielded**) (**marked**) to prevent an arc flash from injuring nearby workers or visitors.

12. Complete statements about types of welding hoods and their characteristics. Circle the material that best completes each of the following statements.

    a. (**Flip-front**) (**Stationary**) filter lens — This type hood has a fixed lens housing with the shaded lens held in by a (**spring retainer**) (**lens clamp**) from where a lens can be slipped out and replaced as welding requires.

    b. (**Flip-front**) (**Stationary**) filter lens — This type hood has a lens housing with a front side that can be flipped up so that it leaves a (**plastic lens**) (**clear view**) that permits the hood to be worn while chipping.

13. Solve problems about guidelines for selecting a safe lens shade for GTAW. Circle the number of the statement that best solves each of the following problems.

    a. You notice a fellow welder putting a #5 lens into a helmet in preparation for a GTAW job. The welder would do well to:

        (1) Remember to weld for only short periods with a #5 lens.

        (2) Weld for no longer than 5 minutes at a time with a #5 lens because that's what the #5 means.

        (3) Remember not to use the GTAW process with anything less than a #8 lens and increase the lens number as the welding current increases.

    b. Another fellow welder wants to know for sure that the correct lens is in the helmet. You could remind your friend that:

        (1) If after welding awhile your eyes feel okay, the lens in probably okay.

        (2) If after welding you see white spots or white blotches as after images, switch to a darker lens shade.

        (3) You should use the lens that gives you the best view of the arc and weld puddle.

14. Solve problems about protective clothing requirements for arc welding. Circle the number of the statement that best solves each of the following problems.

    a. You notice another welder getting ready to weld. The welder is wearing a heavy shirt, but it has no pocket flaps. The welder should.

        (1) Change shirts and wear one with pocket flaps to avoid having sparks or spatter get into the pocket and burn the shirt or the welder, or both.

        (2) Turn a welding cap around so it will not only provide ear protection, but keep sparks away from the shirt pocket.

        (3) Continue with the job. There is little chance a spark could go into an unprotected pocket.

b. You are assigned a GTAW job that has to be done in close quarters where the prospects of sparks falling on your shoulders and back are almost certain. You should.

(1) Wear a leather welding jacket.

(2) Wear a leather welding apron.

(3) Make sure you are wearing a shirt with flaps on the pockets.

c. You notice another welder wearing a pair of heavy leather gloves with gauntlets while working on a GTAW job. The welder could avoid problems manipulating the torch if:

(1) The welder takes the right amount of time with the job.

(2) The welder switches to a pair of lightweight leather gloves made especially for GTAW.

(3) The welder switched to heavy cotton gloves to get more flexibility in hand movements.

15. Complete statements about environmental safety requirements. Circle the material that best completes each of the following statements.

a. Ventilation — Many welding activities produce (**smoke**) (**toxic fumes**) and vapors that are hazardous to breathe, and every work station should be equipped with a ventilation or exhaust system capable of safely removing dangerous and irritating smoke and contaminants.

b. Respirators — In confined areas where the hazard of toxic fumes is increased, a welder should wear an air-supplied respirator or a self-contained breathing apparatus, not a filter-type mask that cannot compensate for (**oxygen displacement**) (**smokey air**).

c. Noise — This is a workplace hazard frequently overlooked, but ear plugs or muffler-type ear protectors should be worn when the work area subjects a welder to high noise levels, especially high noise levels that are (**continuous**) (**irritating**).

d. Lighting — Lighting in a work area or at a work station should be bright enough to provide good visibility free of glare because poorly lit work areas contribute to eye fatigue, irritation, and (**poor work**) (**general health problems**).

***Permission to duplicate this test is granted.**

GTAW Orientation and Safety
Unit 1

Unit Evaluation Form

Student Name _____ Unit Rating _____

Assignment Sheet 1—Solve Problems About GTAW Safety Rating _____

Comments: _____

_____

Written Test Scores

Pretest _____ Posttest _____ Other _____

Other _____

_____

Teacher Signature _____ Date _____

Student Signature _____ Date _____

***Permission to duplicate this form is granted.**

GTAW Orientation and Safety
Unit 1

Information Sheet

1. **Terms and definitions**

   a. **Backup purge** — A gas supplied to the back side of a weldment to prevent atmospheric contamination during the root pass

   b. **Contaminants** — Elements in the atmosphere and/or impurities formed from chemical reactions between a base metal, filler metal, electrode, or shielding gas

   c. **Deposition rate** — The weight of filler metal placed onto a weld in a given period of time

   d. **Gas tungsten arc welding (GTAW)** — An arc welding process that produces coalescence of metals by heating them with an arc between a nonconsumable tungsten electrode and a workpiece; shielding is obtained from a gas

      Note: Pressure may or may not be used, and filler metal may or may not be used.

   e. **Heliarc** — A brand name sometimes used to identify the gas tungsten arc welding process

   f. **Inert gas** — A gas that normally does not combine chemically with a base metal or filler metal

   g. **Nonconsumable** — Material that does not melt or transfer to a weld

   h. **Oxygen displacement** — The tendency of any arc or flame to reduce oxygen in the breathing zone around a welding activity

   i. **Shielding gas** — Protective gas used to prevent atmospheric contamination during a welding procedure

   j. **Toxic hazards** — Poisonous gases, fumes, and vapors produced by chemical reactions in certain welding processes

Information Sheet

2. Advantages of GTAW

a. GTAW uses no flux, produces no slag or spatter, and requires no after-weld cleaning.

b. GTAW is excellent for the root pass on carbon and stainless steel pipe.

c. The controlled heat concentration with GTAW reduces distortion and stress in base metals.

d. The GTAW process is good for welding thin or small items in a variety of metals.

e. With GTAW, the operator can clearly see the arc and weld puddle, and the operator has close control of current and the welding process.

3. Limitations of GTAW

a. GTAW will not function in a windy environment.

b. Deposition rate with GTAW is low, compared to other processes.

c. The slower welding speeds with GTAW increases production costs.

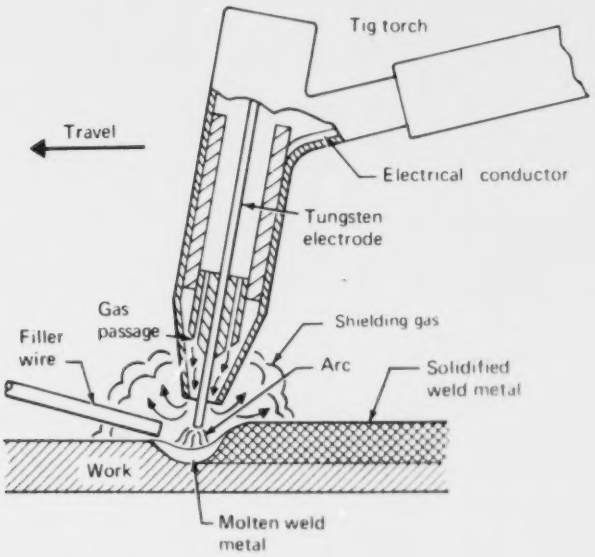
4. Principles of GTAW

a. The heat needed for fusion is generated by an arc between a nonconsumable tungsten electrode and a base metal.

b. As heat is generated from the arc, a shielding gas surrounds the arc stream and the molten puddle formed by the arc and helps to stabilize the arc and protect the puddle from contaminants.

Information Sheet

c. Filler metal may be added with a filler rod inserted into the weld puddle where it is also protected by the shielding gas.



Courtesy Lincoln Electric Company

5. GTAW applications

a. With GTAW, welding is possible in all positions.

b. GTAW can be done on a wide range of metals and thicknesses.

c. GTAW is especially effective where precise heat control is necessary for a quality weld such as in aircraft assembly or small, irregular shaped objects.

d. GTAW is good to excellent for all aluminum applications, and especially good on other thin ferrous and nonferrous metals.

6. Benefits from learning GTAW

a. GTAW introduces a beginning welder to the concept of a nonconsumable electrode and shielding gases and their uses.

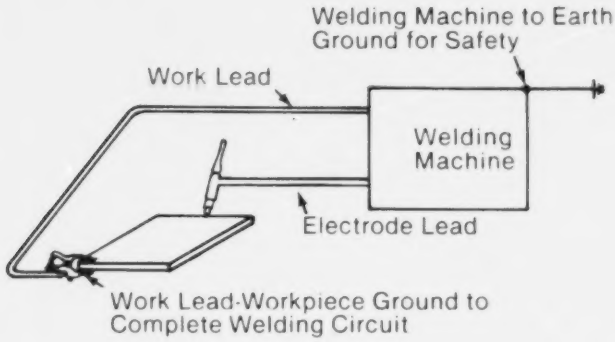
b. GTAW challenges the student to improve manipulative skills and eye-hand coordination.

c. Beginning welders may go to work in a place where there is no opportunity to learn GTAW, so learning GTAW early provides a beginner with an opportunity to achieve skills that will bring better jobs and high pay.

Information Sheet

7. Electrical safety guidelines for GTAW

a. All electrical equipment should have an earth ground for safety reasons, and this ground should not be confused with the work lead to workpiece ground that completes the welding circuit.


Welding Machine to Earth Ground for Safety
Work Lead
Welding Machine
Electrode Lead
Work Lead-Workpiece Ground to Complete Welding Circuit

b. Keep electrical connections tight, clean, and dry because poor connections can heat up, cause bad welds, produce dangerous arcs and sparking, and even melt.

c. Keep work area, equipment, and clothing dry because even a slight amount of moisture can conduct enough electricity to cause a severe shock.

d. Never dip a torch in water to cool it.

e. Disconnect and lock out all electric power sources before doing any work on electrical equipment.

f. Keep welding cables as close to the work area as possible and do not connect cables to building framework because current can be directed through lifting chains and cables and weaken them.

g. When working in high places, carefully examine work area for electrical hazards because a shock in such conditions could cause a fall and severe injury.

h. When using a high frequency intensity control for GTAW, set the control at a minimum setting for the job activity to avoid interfering with nearby communications equipment.

i. Make sure that all GTAW machines using high frequency controls have both input and output grounded to avoid erratic frequency interference.

Note: In production facilities where applications are numerically controlled with punch-type magnetic tape, improper grounding can cause erratic interference that will alter or erase the tapes.

Information Sheet

8. Guidelines for duty cycle safety

a. Duty cycle is a performance reference used to avoid overheating and perhaps ruining a welding machine.

b. Duty cycle is based on a ten minute period and the length of time during that period that a machine can be safely operated.

c. A machine with a 20 percent duty cycle could safely operate 2 minutes out of each 10 minute period.

d. Since duty cycle is rated at the maximum output of a welding machine at a given amperage setting, the lower the percentage, the more attention is required to time spent actually welding.

9. Important rules for handling welding cables and gas and coolant hoses

a. Never drag cables or hoses through dirt or oil, and never pull on a cable to force if over an obstruction.

b. Use only clean dry rags to clean cables and hoses.

CAUTION: Never use gasoline or an oily rag on cables and hoses.

c. When not in use, keep cables and hoses coiled free of kinks and properly stored.

d. Never drape a welding cable over any type of gas cylinder, and NEVER strike an arc on a gas cylinder.

e. Never interchange gas and water hoses.

f. Disconnect and remove electrode holders and cables used for SMAW.

g. Keep cables off metal tables or any grounding surfaces.

h. Make sure water-cooled systems have water turned off when shutting down.

i. Use welding cable covers.

10. Rules for handling hollow castings and containers

a. Vent hollow castings or containers before heating, cutting, or welding on them.

b. Do not heat, cut, or weld on tanks, drums, and sealed containers.

Information Sheet

11. Hazards associated with arc rays

a. A GTAW arc produces ultraviolet and infrared radiation that can severely burn eyes that are unprotected with a proper shade of protective lens.

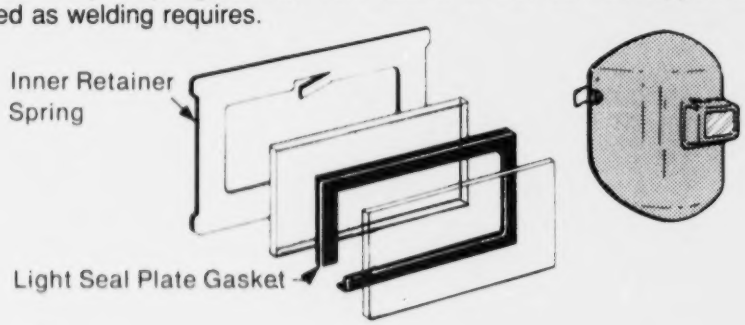
Note: A welding hood or helmet protects the head from flying sparks, but the shaded lens is also required for eye protection.

b. Radiation from a GTAW arc is strong enough to sunburn or sometimes blister bare skin if the exposure is intense or for an extended period, so arms, legs, and torso should be covered with durable flame-resistant clothing.

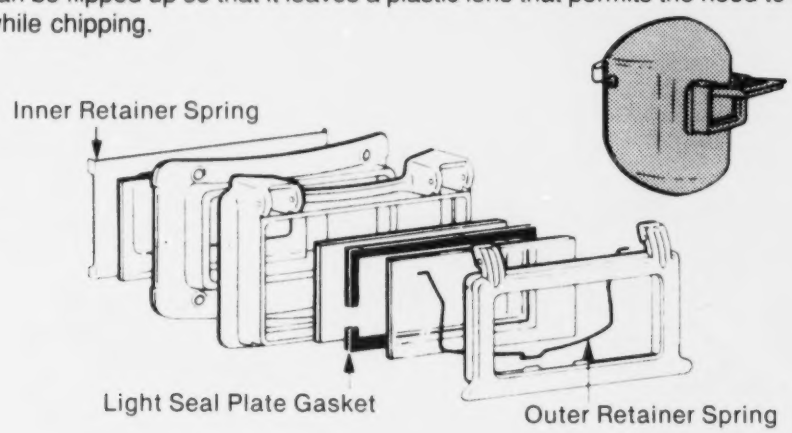
c. Work stations and work areas should be shielded to prevent an arc flash from injuring nearby workers or visitors.

12. Types of welding hoods and their characteristics

a. Stationary filter lens — This type hood has a fixed lens housing with the shaded lens held in by a spring retainer from where a lens can be slipped out and replaced as welding requires.



b. Flip-front filter lens — This type hood has a lens housing with a front side that can be flipped up so that it leaves a plastic lens that permits the hood to be worn while chipping.



Information Sheet

13. Guidelines for selecting a safe lens shade for GTAW

a. Determine electrode size and amperage range for the electrode.

Note: In oxyacetylene welding and cutting, lens shade requirements are based on metal thickness, but in gas-shielded arc welding, lens shade requirements are based on electrode size, amperage range of the electrode, and base metal properties.

b. Select lens shade according to the lens manufacturer's selection chart, but never select less than a #8 lens shade for GTAW.

c. When you remove your hood after welding and you see white spots or white blotches as after images, it means that your are getting too much light through the lens and you should switch to a shade at least one number darker, or check the seal on your lens.

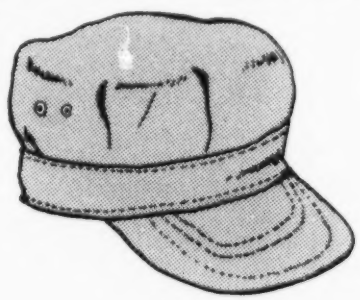
Recommended Lens Shades for Various Welding Current Ranges

Shade No.	Welding Current, A
8	Up to 75
10	75 to 200
12	200 to 400
14	Above 400

Courtesy American Welding Society

14. Protective clothing requirements for arc welding

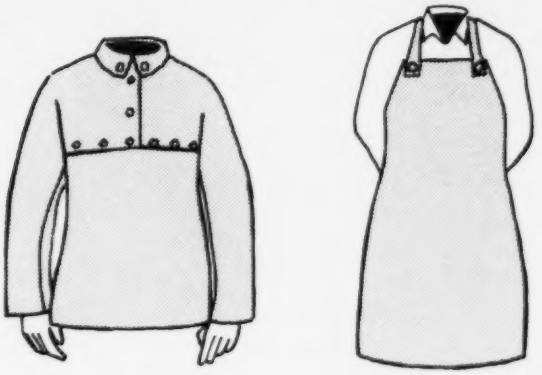
a. Wear a welder's cap that has a flexible bill that can be slipped around to cover an ear and keep sparks or metal spatter out of the ear opening.



b. Wear a heavy, long sleeve shirt with pocket flaps, and heavy cuffless pants that are not frayed at the bottom, and do not wear clothing made of synthetic materials!

Information Sheet

c. For additional protection wear a leather jacket or a leather apron because they will help protect from flying sparks when welding out of position or in confined areas.



d. Select heavy leather boots with uppers that reach above the ankle to prevent burns from sparks and spatter.

Note: Steel-toed boots are recommended for all welding and are sometimes required in hazardous job sites.

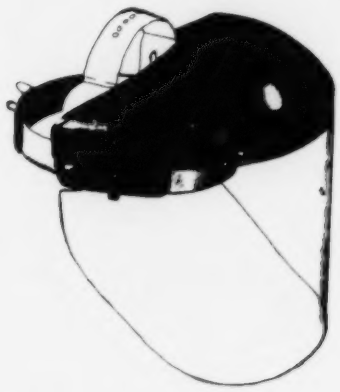
e. Wear lightweight leather gloves designed especially for GTAW.

f. Make sure you have safety glasses with nonmetal frames, impact-resistant lenses, and side shields to protect from flying sparks and spatter.

Note: Wear safety glasses at all times in the shop area.

Information Sheet

g. When grinding or sanding base metals, wear a clear-plastic face shield.



15. Environmental safety requirements

a. Ventilation — Many welding activities produce toxic fumes and vapors that are hazardous to breathe, and every work station should be equipped with a ventilation or exhaust system capable of safely removing dangerous and irritating smoke and contaminants.

> **CAUTION: Over ventilation can interfere with the welding process, so make proper considerations and always position your head out of the path of rising fumes.**

b. Respirators — In confined areas where the hazard of toxic fumes is increased, a welder should wear an air-supplied respirator or a self-contained breathing apparatus, not a filter-type mask that cannot compensate for oxygen displacement.

> **CAUTION: Argon is much heavier than air and will quickly displace oxygen, so be especially careful using the GTAW process in confined areas, even though they appear to have adequate ventilation.**

c. Noise — This is a workplace hazard frequently overlooked, but ear plugs or muffler-type ear protectors should be worn when the work area subjects a welder to high noise levels, especially high noise levels that are continuous.

d. Lighting — Lighting in a work area or at a work station should be bright enough to provide good visibility free of glare because poorly lit work areas contribute to eye fatigue, irritation, and poor work.

GTAW Orientation and Safety
Unit 1

Assignment Sheet 1—Solve Problems Concerning GTAW Safety

Name _____ Overall Rating _____

Directions: Read the following statements carefully; then write a brief statement that recommends a specific solution if there is a safety violation presented.

1. A fellow student is preparing to start a GTAW job in an area where there is obviously some water on the floor. Is there a problem? _____

   Solution: _____

   _____

2. A fellow student has left GTAW cables wrapped around an argon cylinder. Is there a problem? _____

   Solution: _____

   _____

3. A fellow student complains that she sees white spots in front of her eyes every time she stops weld. Is there a problem? _____

   Solution: _____

   _____

4. A fellow student is sanding a piece of aluminum to clean oxide from the surface and is wearing only safety glasses. Is there a problem? _____

   Solution: _____

   _____

5. A fellow student complains that the fumes produced when welding at his work station are very irratating. Is there a problem? _____

   Solution: _____

   _____

GTAW Equipment, Applications, and Techniques Unit 2

Objective Sheet

Unit Objective

After completing this unit, the student should be able to troubleshoot GTAW machine and process problems, and weld to specifications lap joints, T-joints, and butt joints in all positions on mild and stainless steel and aluminum. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to GTAW equipment, application, and techniques with their correct definitions.
2. Match GTAW machine controls with their functions.
3. Complete statements about the concept of pulse current and its use in GTAW.
4. Differentiate between types of GTAW systems.
5. Select true statements about cooling system safety.
6. Complete definitions of types of power cables and their characteristics.
7. Identify basic parts of a GTAW torch.
8. Complete statements about the gas lens and its uses.
9. Match types of nozzles with their functions.
10. Arrange in order the steps in GTAW nozzle selection.
11. Select true statements about GTAW shielding gases and their characteristics.
12. Select true statements about flow meter design and use.
13. Complete statements about flow rates for GTAW shielding gases.

Objective Sheet

14. Complete a chart about tungsten electrodes, their characteristics and applications.

15. Select true statements about guidelines for preparing tungsten electrodes for DC welding.

16. Complete statements about guidelines for grinding electrodes for DC welding.

17. Solve problems about guidelines for preparing electrodes for AC welding.

18. Select true statements about guideline for GTAW electrode extension.

19. Select true statements about guidelines for filler metal selection and use.

20. Complete statements about requirements for base metal preparation.

21. Select true statements about special problems with contamination and air movement.

22. Arrange in order the steps in manual welding with a filler rod.

23. Select true statements about backup bars and their uses in GTAW.

24. Complete statements about guidelines for troubleshooting GTAW problems.

25. Set up a flow meter regulator for GTAW shielding gases. (Job Sheet 1)

26. Set up and shut down GTAW equipment for welding mild or stainless steel. (Job Sheet 2)

27. Prepare mild or stainless steel for GTAW. (Job Sheet 3)

28. Prepare a tungsten electrode for welding mild or stainless steel. (Job Sheet 4)

29. Strike and maintain an arc to make stringer beads on mild or stainless steel without filler metal in the flat position. (Job Sheet 5)

30. Strike and maintain an arc to make stringer beads on mild or stainless steel with filler metal in the flat position. (Job Sheet 6)

31. Weld to specifications a fillet weld lap joint on mild or stainless steel in the flat position. (Job Sheet 7)

32. Weld to specifications a fillet weld T-joint on mild or stainless steel in the flat position. (Job Sheet 8)

Objective Sheet

33. Weld to specifications an open-root square-groove butt joint on mild or stainless steel in the flat position. (Job Sheet 9)

34. Weld to specifications a fillet weld lap joint on mild or stainless steel in the horizontal position. (Job Sheet 10)

35. Weld to specifications a fillet weld T-joint on mild or stainless steel in the horizontal position. (Job Sheet 11)

36. Weld to specifications a fillet weld lap joint on mild or stainless steel in the vertical position. (Job Sheet 12)

37. Weld to specifications a fillet weld T-joint on mild or stainless steel in the vertical position. (Job Sheet 13)

38. Weld to specifications an open-root square-groove butt joint on mild or stainless steel in the vertical position. (Job Sheet 14)

39. Weld to specifications a fillet weld lap joint on mild or stainless steel in the overhead position. (Job Sheet 15)

40. Weld to specifications a fillet weld T-joint on mild or stainless steel in the overhead position. (Job Sheet 16)

41. Set up and shut down GTAW equipment for welding aluminum. (Job Sheet 17)

42. Prepare aluminum for GTAW. (Job Sheet 18)

43. Prepare a tungsten electrode for welding aluminum. (Job Sheet 19)

44. Strike and maintain an arc to make stringer beads on aluminum without filler metal in the flat position. (Job Sheet 20)

45. Strike and maintain an arc to make stringer beads on aluminum with filler metal in the flat position. (Job Sheet 21)

46. Weld to specifications a fillet weld lap joint on aluminum in the flat position. (Job Sheet 22)

47. Weld to specifications a fillet weld T-joint on aluminum in the flat position. (Job Sheet 23)

48. Weld to specifications a square-groove butt joint on aluminum in the flat position. (Job Sheet 24)

49. Weld to specifications a fillet weld lap joint on aluminum in the horizontal position. (Job Sheet 25)

Objective Sheet

50. Weld to specifications a fillet weld T-joint on aluminum in the horizontal position. (Job Sheet 26)

51. Weld to specifications a fillet weld lap joint on aluminum in the vertical position. (Job Sheet 27)

52. Weld to specifications a fillet weld T-joint on aluminum in the vertical position. (Job Sheet 28)

53. Weld to specifications a square-groove butt joint on aluminum in the vertical position. (Job Sheet 29)

54. Weld to specifications a fillet weld lap joint on aluminum in the overhead position. (Job Sheet 30)

55. Weld to specifications a fillet weld T-joint on aluminum in the overhead position. (Job Sheet 31)

GTAW Equipment, Applications, and Techniques
Unit 2

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for enrichment of exceptional students as well as accommodation of special needs students.
4. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.
10. Discuss the job sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of the written test. Add or modify test items as needed.
13. Give written test.
14. Compile job sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignments.
15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Discuss area shops or manufacturers who use gas tungsten arc welding in their production. Invite owners or supervisors to talk to the class about job opportunities for welders with GTAW skills. Skill area: **personal and career development**.

2. Impress upon students the problems posed by contamination in GTAW, not only with the electrode preparation and use, but in all stages of the process, especially improper welding environments. Skill area: **learning to learn**.

3. Take special care with Objectives 15, 16, and 17. Explain the need for careful electrode preparation for both DC and AC welding. Demonstrate how to taper a point and the importance of using a grinding wheel that will not contaminate the electrode. Skill area: **learning to learn**.

4. Demonstrate the use of a filler rod as presented in Objective 22. Stress the importance of not removing the filler rod from the shielded zone during the welding process. Skill area: **learning to learn**.

5. Encourage students to reference the student supplements during training. Student Supplement 1 is vital for troubleshooting both machine and process problems, and Student Supplement 2 should help students better evaluate their abilities with GTAW. Skill area: **learning to learn**.

Resources Used in Developing This Unit

1. Connor, Leonard P., ed. *Welding Handbook Eighth Edition, Vol. 1, Welding Technology*. Miami, FL: American Welding Society, 1987.

2. O'Brien, R. L., ed. *Welding Handbook Eighth Edition, Vol. 2, Welding Processes*. Miami, FL: American Welding Society, 1991.

3. *1988/89 Welding & Fabrication Data Handbook*. Cleveland, OH: Penton Publishing, Inc., 1988.

4. *The Procedure Handbook of Arc Welding, Twelfth Edition*. Cleveland, OH: The Lincoln Electric Company, 1973.

5. *New Lessons in Arc Welding*. Cleveland, OH: The Lincoln Electric Company, 1981.

6. Fortney, Clarence and Mike Gregory. *Gas Tungsten Arc Welding*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1984.

Suggested Activities

Suggested Supplemental Resources

Note: For available programs and single video tapes, see Suggested Supplemental Resources in "GTAW Orientation and Safety, Unit 1."

An added source is item B905 from TPC Training Systems. This is a package of 6 video tapes covering all aspects of GTAW. For Information:

TPC Training Systems
750 Lake Cook Road
Buffalo Grove, IL 60089
Phone: 800-837-8872

Instructions For Evaluating Student Performance

When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure.

Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

GTAW Equipment, Applications, and Techniques
Unit 2

Answers to Written Test

1.

a.	3	e.	2	i.	11
b.	6	f.	8	j.	4
c.	9	g.	5	k.	7
d.	10	h.	1		

2.

a.	4	e.	6	i.	7
b.	1	f.	9	j.	2
c.	8	g.	10	k.	3
d.	5	h.	11		

3. a. Some welding machines
   b. A heat-cool
   c. Minimizes heat build-up

4. a

5. a, b, c, d

6. a. Separate
   b. Water-in lines, water-out line

7. a. Cap
   b. Electrode
   c. Collet
   d. Torch body
   e. Collet body
   f. Nozzle

8. a. Electrode or collet
   b. Laminar flow
   c. An inch or more
   d. With limited access

9. a. 3
   b. 1
   c. 4
   d. 2

10. a. 2
    b. 3
    c. 1

Answers to Written Test

11. Neither statement is true

12. a, c, d

13. a. Air movement
    b. 20
    c. 35, 15
    d. Turbulence
    e. Increased

14. a. 2
    b. 4
    c. 1
    d. 3

15. a, c

16. a. Contamination
    b. 120-grit
    c. Lengthwise with, crosswise over
    d. Above

17. a. 2
    b. 3
    c. 1

18. a, c

19. b, c, d

20. a. Portable sander
    b. Stainless steel brush
    c. Degrease and deoxidize
    d. Allow them to dry before welding starts
    e. No
    f. Air-borne contaminants

21. b, c, d

22. a. 7
    b. 4
    c. 1
    d. 2
    e. 6
    f. 3
    g. 5

23. a, b, c

24. a. Process
    b. Shielding
    c. Elimination
    d. Electrical

GTAW Equipment, Applications, and Techniques
Unit 2

Written Test

1. Match the terms on the right with their correct definitions.

_____a. The amount of current or rate of electron flow in a welding circuit

_____b. The abbreviation for argon shielding gas

_____c. A high frequency AC welding machine power configuration that has negative and positive current roughly equal or balanced

_____d. The standard by which the flow rate of shielding gases is measured

_____e. A tungsten electrode of 99.5% purity which has a relatively low current carrying capacity with AC power and a low resistance to contamination

_____f. A tungsten electrode with 1% or 2% thoria added to give it greater current carrying capacity, longer life, and greater resistance to contamination

_____g. A tungsten electrode with some zirconium oxide added to give it better performance characteristics in certain types of AC welding

_____h. The abbreviation for helium shielding gas

_____i. A long, streamlined flow of shielding gas used to control turbulence around a weld puddle

_____j. A high frequency AC welding machine power configuration that has either the negative or positive current stronger or unbalanced

_____k. The amount of force required to force a current through a given resistance in a welding circuit

1. He
2. EWP
3. Amps
4. Unbalanced wave
5. EWZr
6. Ar
7. Volts
8. EWTh
9. Balanced wave
10. Cfh
11. Laminar flow

2. Match GTAW machine controls with their functions. Place the number of the machine control beside the definition of its function.

_____a. Functions as a pilot arc to bridge the gap between the electrode and base metal and eliminates the need to scratch start the arc

_____b. Functions to permit shielding gases to continue flowing around the electrode after the arc is extinguished to eliminate contamination of the electrode and the weld puddle as they cool

_____c. Provides a general range of amperage selections such as low, medium, high, or maximum, and should never be changed while welding

_____d. Provides a specific amperage selection from minimum to high in low range, minimum to high in medium range, etc.

_____e. Provides quick adjustment for desired polarity, DCEP, AC, and DCEN, and should never be changed while welding

_____f. Reduces current during starting to help eliminate burning the tungsten electrodes or burning through thin gauge metals

_____g. Turns high frequency on or off, provides high frequency for continuous operation with nonferrous metals or start only for ferrous metals

_____h. Provides adjustment of spark intensity for start only or continuous operation

_____i. Provides facility to switch to foot or hand operation or to panel operation

_____j. Provides SMAW or GTAW welding source

_____k. Provides basic power input or shut-off for entire welding machine

1. Post flow
2. Weld control switch
3. Power on-off switch
4. High frequency
5. Fine adjustment current control
6. Polarity switch
7. Remote control switch
8. Current range selector
9. Start adjustment control
10. High frequency spark switch
11. High frequency spark intensity rheostat

3. Complete statements about the concept of pulse current and its use in GTAW. Circle the material that best completes each of the following statements.

   a. (**Some welding machines**) (**All GTAW machines**) have a special setting called "PULSE MODE" or "PULSE."

   b. The pulse setting is used to regulate current so that it establishes (**an on-off**) (**a heat-cool**) pattern that is in timed segments or pulses.

   c. The pulsing action (**maximizes heat input**) (**minimizes heat build-up**) in the base metals, especially thin base metals, and results in minimum distortion and better welds.

4. Differentiate between types of GTAW systems. Place an "X" beside the definition of an air cooled system.

   _____a. Usually suitable for light-duty welding that does not exceed 150 amps, but cannot be used for lengthy periods of continuous welding

   _____b. Required for heavy-duty continuous welding

5. Select true statements about cooling system safety. Place an "X" beside each true statement.

   _____a. Some systems have a fail-safe device that will not allow the welding circuit to be completed until the cooling system is functioning at a required level.

   _____b. Some systems have water flow safety controls so that should the coolant supply diminish, the electrical power source is shut off.

   _____c. Some systems have clear plastic tubing built into the supply lines so the circulating liquid can be monitored visually by the operator.

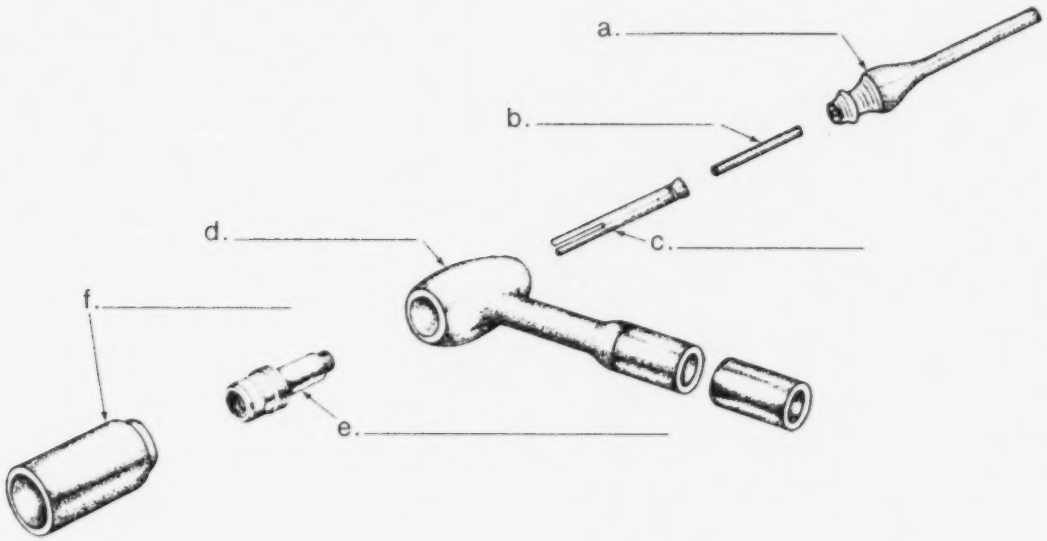
   _____d. All systems should be checked during set-up and monitored periodically during operation to avoid damage to equipment.

6. Complete definitions of types of power cables and their characteristics. Circle the material that best completes each of the following statements.

   a. Air cooled — These types of cables have (**combined**) (**separate**) gas and electric lines encased in a single insulated cover.

   b. Water cooled — These types of cables have separate gas and (**water-in**) (**electric**) lines and a (**torch cable**) (**water-out line**) and power cable that are separate but usually encased in a single insulated cover.

7. Identify basic parts of a GTAW torch by writing the correct part name in the appropriate blank.



8. Complete statements about the gas lens and its uses. Circle the material that best completes each of the following statements.

   a. A gas lens has a porous barrier diffuser with one or more fine mesh screens, and is designed to fit around the (**electrode or the collet**) (**nozzle**).

   b. A gas lens produces a longer, undisturbed flow of shielding gas, a phenomena called (**"laminar flow"**) (**"lens shielding"**).

   c. With a gas lens, an operator can weld with the nozzle (**three inches**) (**an inch or more**) away from the work, and improve the ability to see the weld pool.

   d. Better sight of the weld pool means that an operator has better control working on inside corners or other areas (**with limited access**) (**on overhead welds**).

9. Match types of nozzles with their functions.

_____a.	Most commonly used nozzle because it does an adequate job and is the least expensive	1. Fused quartz
_____b.	A clear-glass nozzle that allows a welder to see through it when good visibility of the weld zone is required	2. Alumina
_____c.	Usually copper and used where application might break other types of nozzles	3. Ceramic
_____d.	Made of high-strength aluminum to give high impact resistance and long life	4. Metal

10. Arrange in order the steps in GTAW nozzle selection. Place a 1 beside the first step, and arrange the other steps in order.

_____a. Use the amperage setting to determine the proper electrode diameter for the job.

_____b. Use the electrode diameter to select the proper gas nozzle, and remember that the gas nozzle size is based on the inside diameter of the nozzle.

_____c. Determine the type of current, DCEN of AC, and the amperage setting you need for the job.

11. Select true statements about GTAW shielding gases and their characteristics. Place an "X" beside each true statement.

Note: For a statement to be true, all parts of the statement must be true.

_____a. Argon

(1) Most popular gas for GTAW
(2) Hard to get
(3) Provides better shielding at lower flow rates than helium because argon is ten times heavier than helium
(4) Provides an easier arc start than helium
(5) Provides better cleaning action when welding aluminum with AC

_____b. Helium

(1) Used only for welding thin metals
(2) Gives a higher heat for comparable current than argon
(3) Requires precise control of arc length
(4) Provides faster welding speeds than argon
(5) Produces poor arc stability and cleaning action
(6) Can be combined in an argon-helium mix to provide high heat input and excellent cleaning on thin gauge metals

12. Select true statements about flow meter design and use. Place an "X" beside each true statement.

_____a. Flow meters regulate the flow of low pressure gases as measured in cubic feet per hour.

_____b. Operate floating-ball type flow meters only in the horizontal position.

_____c. Always use a regulator between the gas supply and the flow meter to assure uniform input pressure to the flow meter.

_____d. Close the adjusting screw when first setting up a gas supply, and then turn it on slowly to make the proper cfh adjustment.

13. Complete statements about flow rates for GTAW shielding gases. Circle the material that best completes each of the following statements.

a. Flow rates for GTAW shielding gases vary with the type of gas, the nozzle size, and (**contaminants**) (**air movement**) in the welding environment.

b. With argon as a shielding gas, (**30**) (**20**) cfh is an almost standard flow rate for DCEN and AC welding.

c. In general, flow rate increases in proportion to the cross-sectional area at the nozzle; this means that some flow rates could range as high as (**45**) (**35**) cfh or as low as (**5**) (**15**) cfh.

d. Excessive flow rates contribute to (**bad visibility**) (**turbulence**) around the weld puddle and usually causes weld problems.

e. Flow rate usually has to be (**increased**) (**decreased**) when welding in the overhead position.

14. Complete a chart about tungsten electrodes, their characteristics and applications. Place the number of the electrode type in the appropriate blank.

Types of Electrode	Color	Finish	Sizes	Applications
a. _____	Green	Ground or Cleaned	1/16, 3/32, 1/8, 5/32, 3/16, 1/4	Aluminum and Magnesium
b. _____	Yellow	Ground or Cleaned	1/16, 3/32, 1/8, 5/32, 3/16, 1/4	Aluminum and Mild or Stainless Steel
c. _____	Red	Ground or Cleaned	1/16, 3/32, 1/8, 5/32, 3/16, 1/4	Aluminum and Mild or Stainless Steel
d. _____	Brown	Ground or Cleaned	1/16, 3/32, 1/8, 5/32, 3/16, 1/4	X-Ray Quality for Aluminum or Magnesium

1. 2% Thoriated
2. Pure
3. Zirconiated
4. 1% Thoriated

15. Select true statements about guiltiness for preparing tungsten electrodes for DC welding. Place an "X" beside each true statement.

_____a. For DC welding on very thin metal or when using low-amperage starting, grind a tungsten electrode on a taper to a fine point.

_____b. If there is a change that a fine point might melt off into the weld deposit, do not taper the electrode.

_____c. Grind the taper so that it is equal in length to 2 to 2½ times the diameter of the electrode.

16. Complete statements about guidelines for grinding electrodes for DC welding. Circle the material that best completes each of the following statements.

a. Grind tungsten electrodes on a grinding wheel reserved especially for use with tungsten in order to avoid (**electrode waste**) (**contamination**).

b. For best results, use a (**90-grit**) (**120-grit**) grinding wheel.

c. Grind the tungsten electrode (**crosswise over**) (**lengthwise with**) the grain of the electrode, not (**lengthwise with**) (**crosswise over**) the grain because that will restrict current flow and cause other welding problems.

d. Position the tungsten (**above**) (**below**) the wheel at an angle that permits consistent shaping without chance that the grinding surface could catch the electrode and ruin the end.

17. Solve problems about guidelines for preparing electrodes for AC welding. Circle the number of the item that best solves each of the following problems.

a. A fellow welder is trying to from the ball tip on a thoriated tungsten electrode by striking it on the aluminum workpiece. The welder should know that:

(1) It is exactly the way it should be done.
(2) A thoriated tungsten electrode should be struck on a piece of copper to form the ball end.
(3) A thoriated tungsten electrode should be tapered before attempting to form the ball end.

b. You notice a fellow welder trying to form the ball end on a thoriated tungsten electrode with the machine set on a high amperage and straight polarity. If you wanted to help your friend, you could:

(1) Remind the welder that the electrode needs proper tapering.
(2) Remind the welder to lower the amperage setting.
(3) Remind the welder to lower the amperage setting, use reverse (DCEP) polarity, and make sure the high frequency control is on "start only."

c. You notice another welder trying to form the ball end on a pure tungsten electrode that has a ¼" diameter. The ball does not form properly, but the welder insists that a pure tungsten electrode should form the proper ball end during the welding process. You could help by:

(1) Reminding the welder that larger diameter electrodes should be tapered even when the end will later be balled for AC welding.
(2) Reminding the welder to start the ball end on a copper block.
(3) Suggesting the welder use a smaller diameter electrode.

18. Select true statements about guidelines for GTAW electrode extension. Place an "X" beside each true statement.

    Note: For a statement to be true, all parts of the statement should be true.

    _____a. Several variables dictate how far a tungsten electrode should be extended form the nozzle:

        (1) Type of welding, DCEN, DCEP, or AC
        (2) Metal thickness
        (3) Joint design
        (4) Welding position

    _____b. One general rule is to make electrode extension as long as possible to improve shielding.

    _____c. Another general rule is that proper electrode extension should give good penetration and shielding, and still provide the operator with a functional view of the weld puddle.

    _____d. Fillet welds almost always require a shorter electrode extension than butt welds.

    _____e. Develop the habit of starting with an electrode extension of about ½" and then adjusting the extension as welding continues.

19. Select true statements about guidelines for filler metal selection and use. Place an "X" beside each true statement.

    _____a. Select a filler metal that is compatible with the joint design.

    _____b. Select the type and size of filler metal according to the type and thickness of the base metal.

    _____c. Keep filler metals clean and free of contamination whether in use or in storage.

    _____d. Do not remove the hot end of the filler wire or rod from the protection of the gas-shielded zone during the welding operation.

20. Complete statements about requirements for base metal preparation. Circle the material that best completes each of the following statements.

    a. Remove mill scale, dirt, and paint from all surfaces with a (**wire brush**) (**portable sander**).

    b. Remove normal surface oxides with a (**wire brush**) (**stainless steel brush**).

    c. Remove heavy oxides, grease, and oil with a shop rag wet with a combination cleaner that will (**degrease and deoxidize**) (**clean and remove paint**) at the same time.

    d. If you use solvents for cleaning, (**weld immediately after cleaning**) (**allow them to dry before welding starts**).

    e. Fit-up is critical in GTAW, so make joint preparation uniform with (**minimum**) (**no**) irregularities or gaps.

    f. Begin welding as soon as possible after the base metal has been prepared to eliminate the chance of (**air-borne contaminants**) (**dust**) adhering to the metal.

21. Select true statements about special problems with contamination and air movement. Place an "X" beside each true statement.

    _____a. Metals that are not properly cleaned before welding may not contaminate a tungsten electrode, but the potential for contamination is present.

    _____b. Work areas that are unclean will add to the potential for contaminants to slow or stop the welding process.

    _____c. Air movement across the weld zone blows the shielding gas away and contributes to immediate contamination of the weld zone.

    _____d. Work areas should be checked for drafts and cross ventilation that could blow shielding gas away, and screens or deflectors should be erected around the work area as needed.

22. Arrange in order the steps for manual welding with a filler rod. Place a "1" beside the first step, and arrange the following steps in order.

_____a. Move torch back to the leading edge of the puddle and repeat the procedure.

_____b. Move the torch back from the puddle away from the direction of travel and angle it at 75-80°.

_____c. Select and prepare tungsten electrode, adjust electrode extension, and adjust machine controls.

_____d. Move the torch so that tungsten electrode comes within ⅛" to 1/16" of the base metal, strike arc and adjust to desired length.

_____e. Withdraw the filler rod from the puddle, but be sure to keep the end of the rod in the shielded zone.

_____f. Hold the torch perpendicular to the base metal and make very slight circular motions until a bright, fluid puddle forms.

_____g. Insert the filler metal rod at a 10-20° angle into the leading edge of the molten pool and let a drop or two of molten metal fill the puddle.

23. Select true statements backup bars and their uses in GTAW. Place an "X" beside each true statement.

_____a. On certain GTAW applications, backup bars (usually copper) may be required to physically support the joint and the weld puddle.

_____b. Backup bars also serve to protect the backside of a weld from contamination and to "chill" or draw heat away from the weld zone.

_____c. In pipe welds and groove welds, welded from one side only, a purging gas should be directed to protect the back side of the weld from contamination.

24. Complete statements about guidelines for troubleshooting GTAW problems. Circle the materials that best completes each of the following statements.

    a. Try to isolate electrical or mechanical problems from (**process**) (**workplace**) problems.

    b. Check the workplace for air movement or drafts that could be causing problems with (**shielding**) (**contamination**).

    c. Change only one variable at a time so you can use a logical process of (**isolation**) (**elimination**) instead of creating a totally different problem.

    d. Observe all safety rules when troubleshooting, especially when troubleshooting (**system**) (**electrical**) problems.

*Permission to duplicate this test is granted.

GTAW Equipment, Applications, and Techniques
Unit 2

Unit Evaluation Form

Student Name _____ Unit Rating _____

Job Sheet 1—Set Up a Flow Meter Regulator for GTAW Shielding Gases Rating _____

Comments: _____

_____

Job Sheet 2—Set Up and Shut Down GTAW Equipment for Welding Mild or Stainless Steel Rating _____

Comments: _____

_____

Job Sheet 3—Prepare Mild or Stainless Steel for GTAW Rating _____

Comments: _____

_____

Job Sheet 4—Prepare a Tungsten Electrode for Welding Mild or Stainless Steel Rating _____

Comments: _____

_____

Job Sheet 5—Strike and Maintain an Arc to Make Stringer Beads on Mild or Stainless Steel Without Filler Metal in the Flat Position Rating _____

Comments: _____

_____

Job Sheet 6—Strike and Maintain an Arc to Make Stringer Beads on Mild or Stainless Steel With Filler Metal in the Flat Position Rating _____

Comments: _____

_____

Job Sheet 7—Weld to Specification a Fillet Weld Lap Joint on Mild or Stainless Steel in the Flat Position Rating _____

Comments: _____

_____

Unit Evaluation Form

Job Sheet 8—Weld to Specifications a Fillet Weld T-Joint on Mild or Stainless Steel in the Flat Position Rating _____

Comments: _____

_____

Job Sheet 9—Weld to Specifications an Open-Root Square-Groove Butt Joint on Mild or Stainless Steel in the Flat Position Rating _____

Comments: _____

_____

Job Sheet 10—Weld to Specifications a Fillet Weld Lap Joint on Mild or Stainless Steel in the Horizontal Position Rating _____

Comments: _____

_____

Job Sheet 11—Weld to Specifications a Fillet Weld T-Joint on Mild or Stainless Steel in the Horizontal Position Rating _____

Comments: _____

_____

Job Sheet 12—Weld to Specifications a Fillet Weld Lap Joint on Mild or Stainless Steel in the Vertical Position Rating _____

Comments: _____

_____

Job Sheet 13—Weld to Specifications a Fillet Weld T-Joint on Mild or Stainless Steel in the Vertical Position Rating _____

Comments: _____

_____

Job Sheet 14—Weld to Specifications a Fillet Weld an Open-Root Square-Groove Butt Joint on Mild or Stainless Steel in the Vertical Position Rating _____

Comments: _____

_____

Unit Evaluation Form

Job Sheet 15—Weld to Specifications a Fillet Weld Lap Joint on Mild or Stainless Steel in the Overhead Position Rating _____

Comments: _____

_____

Job Sheet 16—Weld to Specifications a Fillet Weld T-Joint on Mild or Stainless Steel in the Overhead Position Rating _____

Comments: _____

_____

Job Sheet 17—Set Up and Shut Down GTAW Equipment for Welding Aluminum Rating _____

Comments: _____

_____

Job Sheet 18—Prepare Aluminum for GTAW Rating _____

Comments: _____

_____

Job Sheet 19—Prepare a Tungsten Electrode for Welding Aluminum Rating _____

Comments: _____

_____

Job Sheet 20—Strike and Maintain an Arc to Make Stringer Beads on Aluminum Without Filler Metal in the Flat Position Rating _____

Comments: _____

_____

Job Sheet 21—Strike and Maintain an Arc to Make Stringer Beads on Aluminum With Filler Metal in the Flat Position Rating _____

Comments: _____

_____

Job Sheet 22—Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Flat Position Rating _____

Comments: _____

_____

Unit Evaluation Form

Job Sheet 23—Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Flat Position Rating _____

Comments: _____

_____

Job Sheet 24—Weld to Specifications a Square-Groove Butt Joint on Aluminum in the Flat Position Rating _____

Comments: _____

_____

Job Sheet 25—Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Horizontal Position Rating _____

Comments: _____

_____

Job Sheet 26—Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Horizontal Position Rating _____

Comments: _____

_____

Job Sheet 27—Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Vertical Position Rating _____

Comments: _____

_____

Job Sheet 28—Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Vertical Position Rating _____

Comments: _____

_____

Job Sheet 29—Weld to Specifications a Square-Groove Butt Joint on Aluminum in the Vertical Position Rating _____

Comments: _____

_____

Unit Evaluation Form

Job Sheet 30—Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Overhead Position Rating _____

Comments: _____

_____

Job Sheet 31—Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Overhead Position Rating _____

Comments: _____

_____

Written Test Scores

Pretest _____ Posttest _____ Other _____

Other _____

_____

Teacher Signature _____ Date _____

Student Signature _____ Date _____

***Permission to duplicate this form is granted.**

GTAW Equipment, Applications, and Techniques
Unit 2

Information Sheet

1. **Terms and definitions**

   a. **Amps** — The amount of current or rate of electron flow in a welding circuit

   b. **Ar** — The abbreviation for argon shielding gas

   c. **Balanced wave** — A high frequency AC welding machine power configuration that has negative and positive current roughly equal or balanced

   d. **Cfh (cubic feed per hour)** — The standard by which the flow rate of shielding gases is measured

   e. **EWP** — A tungsten electrode of 99.5% purity which has a relatively low current carrying capacity with AC power and a low resistance to contamination

   f. **EWTh** — A tungsten electrode with 1% or 2% thoria added to give it greater current carrying capacity, longer life, and greater resistance to contamination

   g. **EWZr** — A tungsten electrode with some zirconium oxide added to give it better performance characteristics in certain types of AC welding

   h. **He** — The abbreviation for helium shielding gas

   i. **Laminar flow** — A long, streamlined flow of shielding gas used to control turbulence around a weld puddle

   j. **Unbalanced wave** — A high frequency AC welding machine power configuration that has either the negative or positive current stronger or unbalanced

   k. **Volts** — The amount of force required to force a current through a given resistance in a welding circuit

2. **GTAW machine controls and their functions**

   a. **High frequency** — Functions as a pilot arc to bridge the gap between the electrode and base metal and eliminates the need to scratch start the arc

   b. **Post flow** — Functions to permit shielding gases to continue flowing around the electrode after the arc is extinguished to eliminate contamination of the electrode and the weld puddle as they cool

   c. **Current selectors** (amperage controls)

      (1) **Current range selector** — Provides a general range of amperage selections such as low, medium, high, or maximum, and should never be changed while welding

(2) **Fine adjustment current control** — Provides a specific amperage selection from minimum to high in low range, minimum to high in medium range, etc.

d. **Polarity switch** — Provides quick adjustment for desired polarity, DCEP, AC, and DCEN, and should never be changed while welding

e. **Start adjustment control (soft-start switch)** — Reduces current during starting to help eliminate burning the tungsten electrodes or burning through thin gauge metals

f. **High frequency spark switch** — Turns high frequency on or off, provides high frequency for continuous operation with nonferrous metals or start only for ferrous metals

g. **High frequency spark intensity rheostat** — Provides adjustment of spark intensity for start only or continuous operation

h. **Remote control switch** — Provides facility to switch to foot or hand operation or to panel operation

i. **Weld control switch** — Provides SMAW or GTAW welding source

j. **Power on-off switch** — Provides basic power input or shut-off for entire welding machine

3. The concept of pulse current and its use in GTAW

a. Some welding machines have a special setting called "PULSE MODE" or "PULSE."

b. The pulse setting is used to regulate current so that it establishes a heat-cool pattern that is in timed segments or pulses.

c. The pulsing action minimizes heat build-up in the base metals, especially thin base metals, and results in minimum distortion and better welds.

4. Types of GTAW systems and their characteristics

a. **Air cooled** — Usually suitable for light-duty welding that does not exceed 150 amps, but cannot be used for lengthy periods of continuous welding

b. **Water cooled** — Required for heavy-duty continuous welding and frequently uses anti-freeze or a water-soluble oil in a self-contained system, but may use tap water as a coolant

Information Sheet

5. Cooling system safety

a. Some systems have a fail-safe device that will not allow the welding circuit to be completed until the cooling system is functioning at a required level.

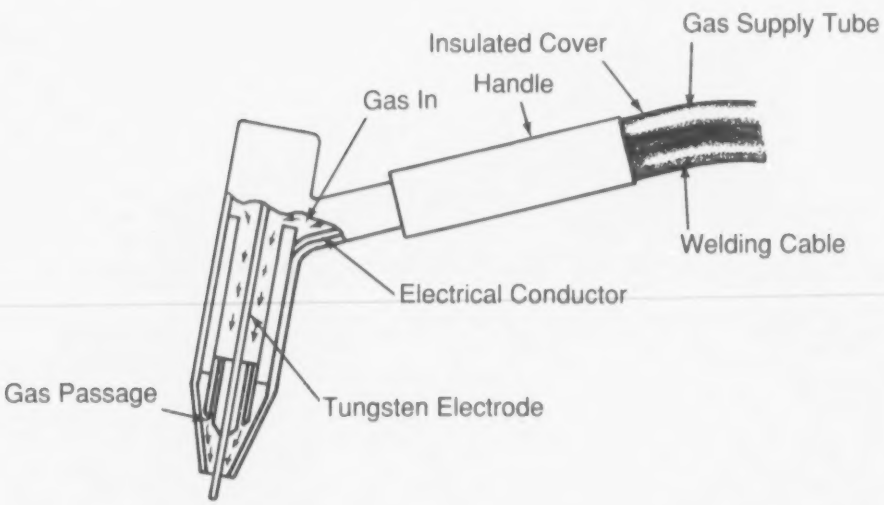
b. Some systems have water flow safety controls so that should the coolant supply diminish, the electrical power source is shut off.

c. Some systems have clear plastic tubing built into the supply lines so the circulating liquid can be monitored visually by the operator.

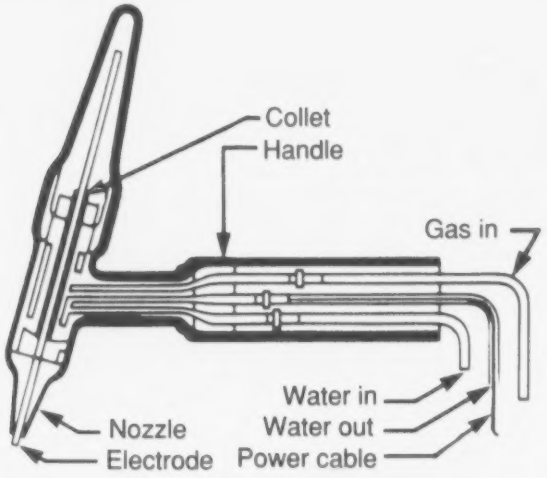
d. All systems should be checked during set-up and monitored periodically during operation to avoid damage to equipment.

6. Types of power cables and their characteristics

a. **Air cooled** — These types of cables have separate gas and electric lines encased in a single insulated cover.



b. **Water cooled** — These types of cables have separate gas and water-in lines and a water-out line and power cable that are separate but usually encased in a single insulated cover.



Courtesy American Welding Society

7. **Parts of a GTAW torch and their functions**

a. **Cap** — Hold and tightens tungsten electrode in collet

b. **Electrode** — Acts as a nonconsumable conductor of the welding current

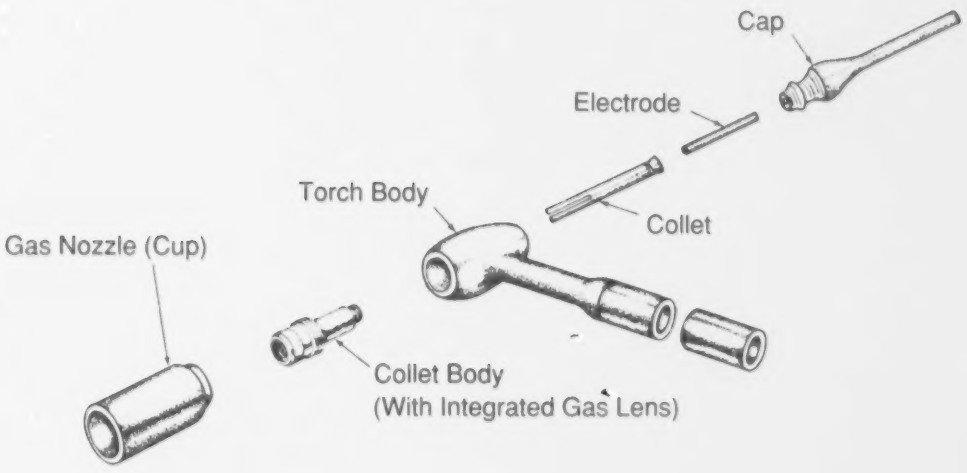
c. **Collet** — Used to guide, center, and hold the electrode

d. **Torch body** — Provides housing for electrode, collet, collet body, and fitting ends for gas and water supplies

e. **Collet body** — Holds collet and electrode, diffuses shielding gas, and anchors nozzle (may have an integrated gas lens)

Information Sheet

f. **Nozzle** — A device that directs the flow of shielding gas around the electrode and into the weld zone to prevent contamination



8. The gas lens and its uses

a. A gas lens has a porous barrier diffuser with one or more fine mesh screens, and is designed to fit around the electrode or the collet.

b. A gas lens produces a longer, undisturbed flow of shielding gas, a phenomena called "laminar flow".

c. With a gas lens, an operator can weld with the nozzle an inch or more away from the work, and improve the ability to see the weld pool.

d. Better sight of the weld pool means that an operator has better control working on inside corners or other areas with limited access.

Information Sheet

9. Types of nozzles and their functions

a. **Ceramic** — Most commonly used nozzle because it does an adequate job and is the least expensive

b. **Fused quartz** — A clear-glass nozzle that allows a welder to see through it when good visibility of the weld zone is required

c. **Metal** — Usually copper and used where application might break other types of nozzles

d. **Alumina fused quartz** — Made of high-strength aluminum to give high impact resistance and long life

10. Steps in GTAW nozzle selection

a. Determine the type of current, DCEN, DCEP, or AC, and the amperage setting you need for the job.

b. Use the amperage setting to determine the proper electrode diameter for the job.

c. Use the electrode diameter to select the proper gas nozzle, and remember that the gas nozzle size is based on the inside diameter of the nozzle.

Note: In the following AWS table, all values are based on using argon as a shielding gas. EWTh-2[b] electrodes are recommended for DCEN and DCEP, and EWP[c] electrodes are recommended for AC welding.

Electrode Diameter		Use Gas Nozzle I.D.	Direct Current, A		Alternating Current, A	
			Straight Polarity[b]	Reverse Polarity[b]	Unbalanced Wave[c]	Balanced Wave[c]
in.	mm.	in.	DCEN	DCEP		
0.010	0.25	¼	up to 15		up to 15	up to 15
0.020	0.50	¼	5-20		5-15	10-20
0.040	1.00	⅜	15-18		10-60	20-30
1/16	1.6	⅜	70-150	10-20	50-100	30-80
3/32	2.4	½	150-250	15-30	100-160	60-130
⅛	3.2	½	250-400	25-40	150-210	100-180
5/32	4.0	½	400-500	40-55	200-275	160-240
3/16	4.8	⅝	500-750	55-80	250-350	190-300
¼	6.4	¾	750-1100	80-125	325-450	325-450

Courtesy American Welding Society

Information Sheet

11. GTAW shielding gases and their characteristics

a. Argon (Ar)

(1) Most popular gas for GTAW

(2) Good availability

(3) Provides better shielding at lower flow rates than helium because argon is ten times heavier than helium

(4) Provides an easier arc start than helium

(5) Provides better cleaning action when welding aluminum with AC

b. Helium (He)

(1) Frequently used for welding thicker metals

(2) Gives a higher heat for comparable current than argon

(3) Requires precise control of arc length

(4) Provides faster welding speeds than argon

(5) Produces poor arc stability and cleaning action

(6) Can be combined in an argon-helium mix to provide high heat input and excellent cleaning on thicker gauge metals

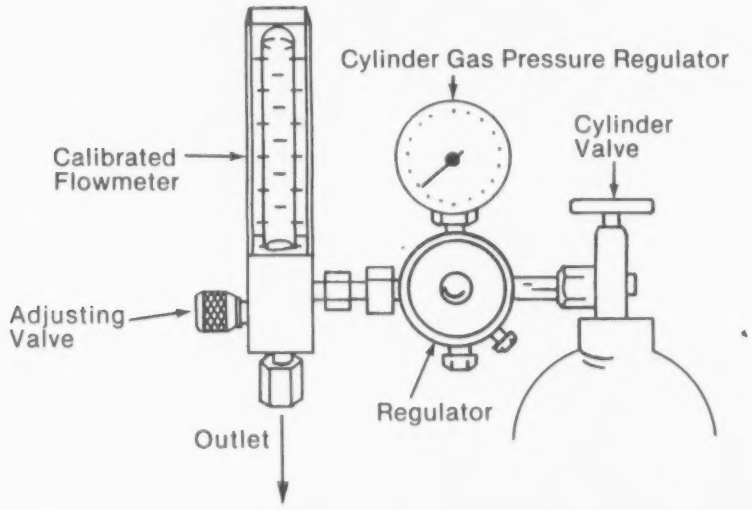
12. Flow meter design and use

a. Flow meters regulate the flow of low pressure gases as measured in cubic feet per hour (cfh).

b. Operate floating-ball type flow meters only in the vertical position.

c. Always use a regulator between the gas supply and the flow meter to assure uniform input pressure to the flow meter.

d. Close the adjusting screw when first setting up a gas supply, and then turn it on slowly to make the proper cfh adjustment.



13. Flow rates for GTAW shielding gases

a. Flow rates for GTAW shielding gases vary with the type of gas, the nozzle size, and air movement in the welding environment.

b. With argon as a shielding gas, 20 cfh is an almost standard flow rate for DCEN and AC welding.

c. In general, flow rate increases in proportion to the cross-sectional area at the nozzle; this means that some flow rates could range as high as 35 cfh or as low as 15 cfh.

d. Excessive flow rates contribute to turbulence around the weld puddle and usually causes weld problems.

e. Flow rate usually has to be increased when welding in the overhead position.

Information Sheet

14. Tungsten electrodes, their characteristics and applications

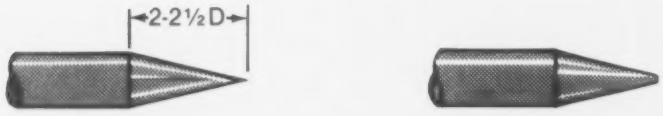
Types of Electrode	Color	Finish	Sizes	Applications
Pure (EWP)	Green	Ground or Cleaned	1/16, 3/32, 1/8, 5/32, 3/16, 1/4	Aluminum and Magnesium
1% Thoriated (EWTh-1)	Yellow	Ground or Cleaned	1/16, 3/32, 1/8, 5/32, 3/16, 1/4	Aluminum and Mild or Stainless Steel
2% Thoriated (EWTh-2)	Red	Ground or Cleaned	1/16, 3/32, 1/8, 5/32, 3/16, 1/4	Aluminum and Mild or Stainless Steel
Zirconiated (EWZr-1)	Brown	Ground or Cleaned	1/16, 3/32, 1/8, 5/32, 3/16, 1/4	X-Ray Quality for Aluminum or Magnesium

15. Guidelines for preparing electrodes for DC welding

a. For DC welding on very thin metal or when using low-amperage starting, grind a tungsten electrode on a taper to a fine point.

b. If there is a chance that a fine point might melt off into the weld deposit, taper the electrode to a blunt point.

c. Grind the taper so that it is equal in length to 2 to 2½ times the diameter of the electrode.



Sharp Point Blunt Point

Note: Tungsten electrodes can also be sharpened chemically by dipping a hot electrode into a container of sodium nitrate, but the process is used only in special applications.

Information Sheet

16. Guidelines for grinding electrodes for DC welding

a. Grind tungsten electrodes on a grinding wheel reserved especially for use with tungsten in order to avoid contamination.

b. For best results, use a 120-grit grinding wheel.

c. Grind the tungsten electrode lengthwise with the grain of the electrode, not crosswise over the grain because that will restrict current flow and cause other welding problems.

d. Position the tungsten above the wheel at an angle that permits consistent shaping without chance that the grinding surface could catch the electrode and ruin the end.

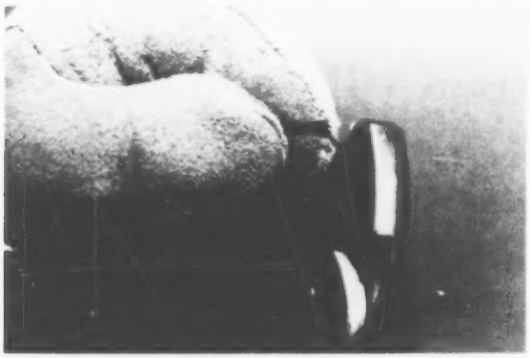
17. Guidelines for preparing electrodes for AC welding

a. Tungsten electrodes used for AC welding on aluminum require a ball tip.

b. With pure tungsten electrodes, form the ball tip by striking the electrode on aluminum and the ball will form during the welding process.

Information Sheet

c. With a used or contaminated thoriated tungsten electrodes, nick the electrode on a grinding wheel and break the end off with a pair of pliers and then prepare the electrode as you would a new one.



d. To form the ball on a thoriated tungsten electrode, strike the end with the clean break on a piece of copper with the high frequency control on "start only," and in reverse polarity (DCEP) with a low amp setting.

e. Smaller tungsten electrodes (0.010-0.040) are difficult to taper, but larger electrodes (1/16-1/4), both pure and thoriated tungsten, should be tapered even when the end will later be balled for AC welding.

f. The length of the taper on larger electrodes should be about twice the diameter of the electrode, and the ball end should be no more than 1½ times the diameter of the electrode at the tapered end.

18. Guidelines for GTAW electrode extension

a. Several variables dictate how far a tungsten electrode should be extended from the nozzle:

(1) Type of welding, DCEN, DCEP, or AC

(2) Metal thickness

(3) Joint design

(4) Welding position

b. One general rule is to make electrode extension as short as possible to improve shielding.

c. Another general rule is that proper electrode extension should give good penetration and shielding, and still provide the operator with a functional view of the weld puddle.

d. Fillet welds almost always require a longer electrode extension than butt welds.

e. Develop the habit of starting with an electrode extension of about ⅛" and then adjusting the extension as welding continues.

19. Guidelines for filler metal selection and use

a. Select a filler metal that is compatible with the base metal.

b. Select the type and size of filler metal according to the type and thickness of the base metal.

c. Keep filler metals clean and free of contamination whether in use or in storage.

d. Do not remove the hot end of the filler wire or rod from the protection of the gas-shielded zone during the welding operation.

20. Requirements for base metal preparation

a. Remove mill scale, dirt, and paint from all surfaces with a portable sander.

b. Remove normal surface oxides with a stainless steel brush.

c. Remove heavy oxides, grease, and oil with a shop rag wet with a combination cleaner that will degrease and deoxidize at the same time.

d. If you use solvents for cleaning, allow them to dry before welding starts.

Caution: Many solvent cleaners and deoxidizers are highly flammable and should be used with care.

e. Fit-up is critical in GTAW, so make joint preparation uniform with no irregularities or gaps.

f. Begin welding as soon as possible after the base metal has been prepared to eliminate the chance of air-borne contaminants adhering to the metal.

Information Sheet

21. Special problems with contamination and air movement

a. Metals that are not properly cleaned before welding starts will immediately contaminate a tungsten electrode, make welding difficult or impossible, and waste valuable time.

b. Work areas that are unclean will add to the potential for contaminants to slow or stop the welding process.

c. Air movement across the weld zone blows the shielding gas away and contributes to immediate contamination of the weld zone.

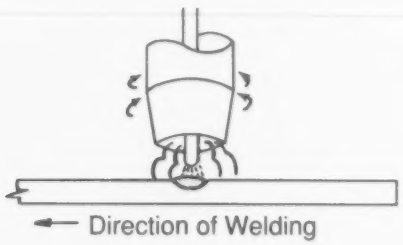
d. Work areas should be checked for drafts and cross ventilation that could blow shielding gas away, and screens or deflectors should be erected around the work area as needed.

22. Steps for manual welding with a filler rod

a. Select and prepare tungsten electrode, adjust electrode extension, and adjust machine controls.

b. Move the torch so that tungsten electrode comes within ⅛" to 1/16" of the base metal, strike arc and adjust to desired length.

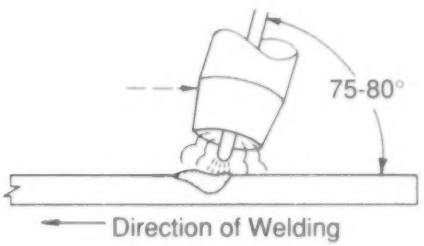
c. Hold the torch perpendicular to the base metal and make very slight circular motions until a bright, fluid puddle forms.



Courtesy Lincoln Electric Company

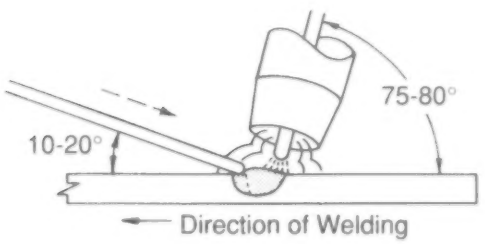
Information Sheet

d. Move the torch back from the puddle away from the direction of travel and angle it at 75-80°.



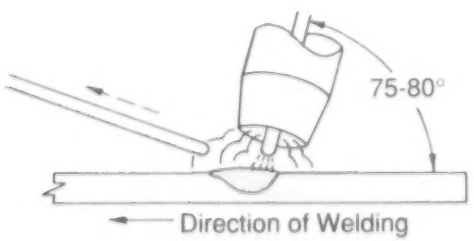
Courtesy Lincoln Electric Company

e. Insert the filler metal rod at a 10-20° angle into the leading edge of the molten pool and let a drop or two of molten metal fill the puddle.



Courtesy Lincoln Electric Company

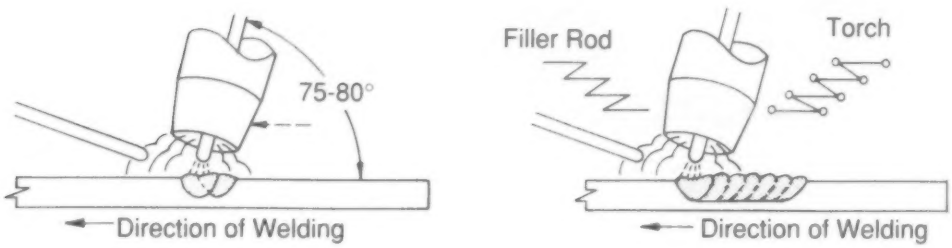
f. Withdraw the filler rod from the puddle, but be sure to keep the end of the rod in the shielded zone.



Courtesy Lincoln Electric Company

Information Sheet

g. Move torch back to the leading edge of the puddle and repeat the procedure.



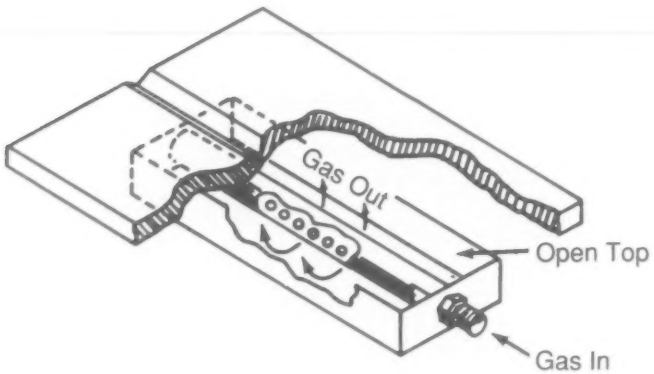
Courtesy Lincoln Electric Company

23. Backup bars and their use in GTAW

a. On certain GTAW applications, backup bars (normally copper) may be required to physically support the joint and the weld puddle.

b. Backup bars also serve to protect the backside of a weld from contamination and to "chill" or draw heat away from the weld zone.

c. In pipe welds and groove welds, welded from one side only, a purging gas should be directed to protect the back side of the weld from contamination.



Courtesy American Welding Society

Information Sheet

24. Guidelines for troubleshooting GTAW problems

a. Try to isolate electrical or mechanical problems from process problems.

Example: Contamination in a weld could be caused by improper electrode preparation, but it might also be caused by an improper flow rate of shielding gas.

b. Check the workplace for air movement or drafts that could be causing problems with shielding.

c. Change only one variable at a time so you can use a logical process of elimination instead of creating a totally different problem.

d. Observe all safety rules when troubleshooting, especially when troubleshooting electrical problems.

Note: See Student Supplement 1 for GTAW troubleshooting guidelines from the American Welding Society. Student Supplement 2 contains valuable reference information for evaluating good and poor welds with materials from Miller Electric Mfg. Co.

GTAW Equipment, Applications, and Techniques
Unit 2

Student Supplement 1—Troubleshooting Guides for Gas Tungsten Arc Welding

Problem	Cause	Remedy
Excessive electrode consumption	1. Inadequate gas flow.	1. Increase gas flow.
	2. Operating on reverse polarity.	2. Use larger electrode or change to straight polarity.
	3. Improper size electrode for current required.	3. Use larger electrode.
	4. Excessive heating in holder.	4. Check for proper collet contact.
	5. Contaminated electrode.	5. Remove contaminated portion. Erratic results will continue as long as contamination exists.
	6. Electrode oxidation during cooling.	6. Keep gas flowing after stopping arc for at least 10 to 15 seconds.
	7. Using gas containing oxygen or CO_2.	7. Change to proper gas.
Erratic arc	1. Base metal is dirty, greasy.	1. Use appropriate chemical cleaners, wire brush, or abrasive.
	2. Joint too narrow.	2. Open joint groove; bring electrode closer to work; decrease voltage.
	3. Electrode is contaminated.	3. Remove contaminated portion of electrode.
	4. Arc too long.	4. Bring holder closer to work to shorten arc.
Porosity	1. Entrapped gas impurities (hydrogen, nitrogen, air, water vapor).	1. Blow out air from all lines before striking arc; remove condensed moisture from lines; use welding grade (99.99%) inert gas.
	2. Defective gas hose or loose hose connections.	2. Check hose and connections for leaks.
	3. Oil film on base metal.	3. Clean with chemical cleaner not prone to break up in arc; DO NOT WELD WHILE BASE METAL IS WET.
Tungsten contamination of workpiece	1. Contact starting with electrode.	1. Use high frequency starter; use copper striker plate.
	2. Electrode melting and alloying with base metal.	2. Use less current or larger electrode; use thoriated or zirconium-tungsten electrode.
	3. Touching tungsten to molten pool.	3. Keep tungsten out of molten pool.

Courtesy American Welding Society

GTAW Equipment, Applications, and Techniques
Unit 2

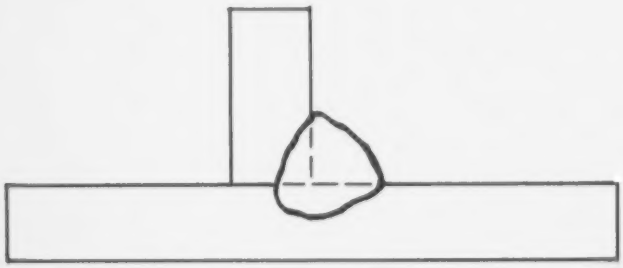
Student Supplement 2—Evaluating Good Welds and Poor Welds

Evaluating Good Welds

1. Examine the weld for proper build-up with good penetration and bead edges fused in.
2. Look for a weld that is clean and bright with an even ripple and a smooth edge.
3. On a butt weld, look for uniform width and correct bead size.

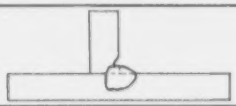
Courtesy Miller Electric Mfg. Co.

4. On a fillet weld, look for the legs of the fillet to equal the metal thickness.
5. On a fillet weld, look for no undercutting and a bead face that is slightly convex.



Courtesy Miller Electric Mfg. Co.

Student Supplement 2

Problem	Appearance	Cause
Excessive build-up Poor penetration Poor fusion at edges		Welding current too low
Bead too wide and flat Undercut at edges Excessive burn through		Welding current too high
Bead too small Insufficient penetration Ripples widely spaced		Travel speed too fast
Bead too wide Excessive build-up Excessive penetration		Travel speed too slow
Undercut Insufficient weld deposit Uneven penetration		Welding current too high and/or wrong placement of filler rod
Poor penetration Poor fusion		Faulty joint preparation and too low welding current

Courtesy Miller Electric Mfg. Co.

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 1—Set Up a Flow Meter Regulator for GTAW Shielding Gases

Name _____ Attempt Number _____

Date _____ Overall Rating _____

Evaluation criteria	Rating
Cylinder safety	_____
Regulator installation	_____
Flow meter adjusting valve operation	_____
Flow meter adjustment	_____

A. Tools and materials

GTAW machine with accessories
Argon or helium cylinder
Flow meter regulator
Adjustable wrench or ⅞" open-end wrench
Safety glasses

B. Procedure

☐ 1. Check to see that gas cylinder is safely secured in an upright position.

☐ 2. Remove cylinder cap.

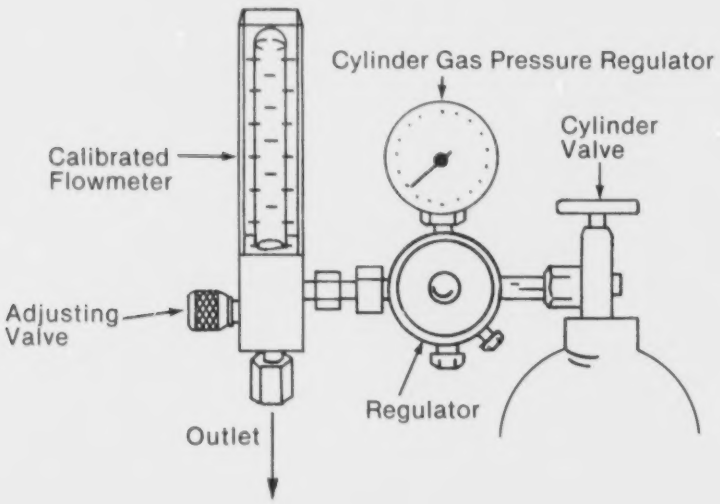
☐ 3. Crack cylinder valve slightly to clear cylinder valve fitting.

☐ 4. Attach flow meter regulator to the cylinder valve so that it is vertical.

☐ 5. Tighten regulator fitting nut with wrench, but do not over tighten.

Job Sheet 1

☐ 6. Check to make sure that flow meter adjusting valve is shut off, and if it isn't, turn it clockwise until it is tight.



☐ 7. Stand to one side and open gas cylinder valve all the way so that it will back seat against the top of the valve.

☐ 8. Set up and turn on GTAW machine.

Note: Check with instructor.

☐ 9. Turn flow meter adjusting screw counterclockwise until the ball starts to rise in the flow meter.

Note: If ball is not rising, depress foot pedal or check post flow timer.

☐ 10. Move the adjusting valve clockwise or counterclockwise to make adjustment to CFH desired.

Note: The very top of the ball is the reference point for measuring CFH.

☐ 11. Have your instructor check your work.

☐ 12. Shut down and secure equipment.

☐ 13. Return tools to proper storage.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 2—Set Up and Shut Down GTAW Equipment for Welding Mild or Stainless Steel

Name _____ Attempt Number _____

Date _____ Overall Rating _____

Evaluation criteria	Rating
Set up and machine settings	_____
Flow meter setting	_____
Coolant system check	_____
Tungsten electrode preparation	_____
Shut down safety	_____

A. Tools and materials

GTAW machine with accessories
Personal safety clothing and equipment
Tungsten electrode
Shielding gas as selected by instructor
Safety glasses

B. Procedure

☐ 1. Set up power supply.

☐ 2. Set current range selector according to metal thickness.

☐ 3. Set polarity switch to DCEN.

☐ 4. Set weld control switch to GTAW.

☐ 5. Set high frequency switch to "START ONLY" position.

☐ 6. Set spark control for soft start.

☐ 7. Set remote control switch for contactor or amperage control to either remote or panel depending on machine accessories.

Job Sheet 2

- ☐ 8. Set post flow timer according to electrode size.
- ☐ 9. Turn on cylinder valve and adjust flow meter regulator to rate of flow recommended for electrode.
- ☐ 10. Check for proper and complete circulation in the cooling system and verify that there are no leaks.
- ☐ 11. Select correct size collet and gas nozzle according to electrode size.
- ☐ 12. Prepare the tungsten electrode with a pointed tip. (See Job Sheet 4)
- ☐ 13. Adjust the electrode extension to no more than ⅛".
- ☐ 14. Connect ground clamp to base metal.
- ☐ 15. Switch machine on.
- ☐ 16. Have your instructor check your set-up procedure.
- ☐ 17. Prepare for shut-down procedure.
- ☐ 18. Close gas cylinder valve.
- ☐ 19. Depress foot control to bleed gas line.
- ☐ 20. Shut off flow meter regulator.
- ☐ 21. Turn off cooling system.
- ☐ 22. Turn off power switch.
- ☐ 23. Remove electrode from torch and return to proper storage.
- ☐ 24. Remove collet and gas nozzle and return to proper storage.
- ☐ 25. Disconnect ground clamp.
- ☐ 26. Roll cables up neatly and clean up work station.
- ☐ 27. Return tools and materials to proper storage.
- ☐ 28. Have your instructor check you shut down procedure.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 3—Prepare Mild or Stainless Steel for GTAW

Name _____ Attempt Number _____

Date _____ Overall Rating _____

Evaluation criteria	Rating
Scale removal	_____
Edge preparation	_____
Wire or stainless brush use	_____
Washing, drying, and wiping	_____

A. Tools and materials

Mild or stainless steel as selected by instructor
Wire and stainless steel brushes
Portable grinder with sanding attaching
Pliers and clamps
Combination cleaner-deoxidizer
Clean shop rags
Safety clothing, safety glasses, and face shield

B. Procedure

- ☐ 1. Secure workpiece with clamps or vise.
- ☐ 2. Remove all scale, rust, dirt, and paint from all surfaces with portable sander.
- ☐ 3. Grind edges of joints for specified edge preparation.
- ☐ 4. Wire brush or stainless steel brush as required.
- ☐ 5. Wash stainless steel with a solution of cleaner-deoxidizer and allow to air dry before welding.
- ☐ 6. Wipe mild steel down with a clean, dry shop rag and store in a dry place prior to welding.
- ☐ 7. Have your instructor check your work.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 4—Prepare a Tungsten Electrode for Welding Mild or Stainless Steel

Name _____ Attempt Number _____

Date _____ Overall Rating _____

Evaluation criteria	Rating
Tungsten placement on wheel	_____
Tungsten shaping with grain	_____
Quality taper and point	_____

A. Tools and materials

Pedestal grinder
Minimum 120-grit grinding wheel
1 - 2% tungsten electrode as selected by instructor
Safety clothing, safety glasses, and face shield

B. Procedure

☐ 1. Determine diameter of electrode.

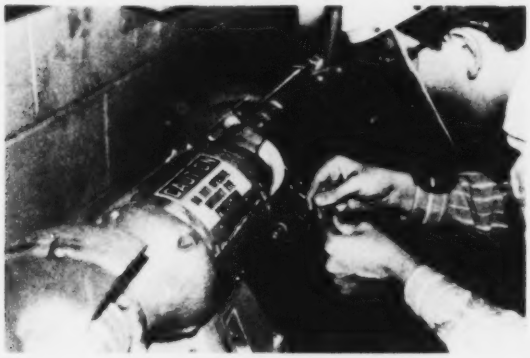
☐ 2. Measure or estimate a distance equal to two or two and a half times the diameter of the electrode to serve as a guide for length of point.

☐ 3. Turn grinder on and allow wheel to reach full rpm.

Job Sheet 4

☐ 4. Hold the electrode firmly and place it gently against the grinder so that direction of grinding will run in the direction of the length of the electrode and not crosswise to the length.

> **Caution: Manipulate the electrode with your fingers and don't allow the end of the electrode to jab the palm of your hand.**



☐ 5. Turn the tungsten slowly as you grind to give a uniform bevel to the grind and keep the point of the electrode at the center.

☐ 6. Grind the electrode to a needle point for a job that calls for low amperage starting on thin gauge metal.

☐ 7. Have your instructor check your work.

☐ 8. Dull the point slightly on the grinding wheel for a job that calls for higher amperage welding on thicker gauge metal.

☐ 9. Have your instructor check your work.

☐ 10. If the electrode appears to be contaminated, nick a spot near the end on the grinding wheel, break the tip off with pliers, and grind the electrode again.

☐ 11. Turn grinder off.

☐ 12. Have your instructor check your work.

☐ 13. Secure equipment and return tools and materials to proper storage.

Evaluator's comments: _____

_____

_____

Job Sheet 5—Strike and Maintain an Arc to make
Stainless Steel Without Filler Metal in t

Name _____

Date _____

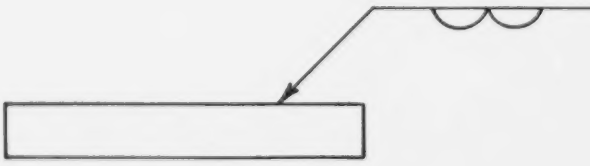
Evaluation criteria
Equipment setup and safety
Electrode extension
Shielding gas adjustment
Stinger bead quality

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Mild or stainless steel as selected by instructor
Wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



2. Filler metal: N/A

3. Tungsten: 1-2% thoriated

cations, and Techniques
t 2

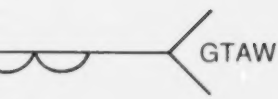
rc to make Stringer Beads on Mild or
r Metal in the Flat Position

_____ Attempt Number _____

_____ Overall Rating _____

	Rating
	_____
	_____
	_____
	_____

structor



Job Sheet 5

4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: Flat
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

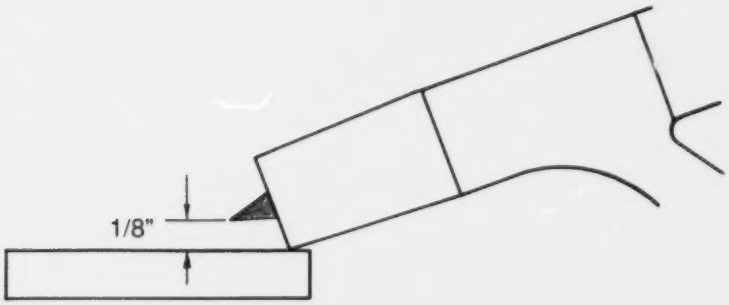
C. Procedure

☐ 1. Set up equipment as previously outlined.

☐ 2. Double check electrode extension and shielding gas flow rate.

☐ 3. Position plate in accordance with specifications, and hold torch with right hand, if right handed, or opposite if left handed.

☐ 4. Move torch so that nozzle rests on base metal with electrode about ⅛″ off base metal.



☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

Job Sheet 5

☐ 6. Correct electrode angle the moment the arc is established.

Side View Front View

Courtesy Lincoln Electric Company

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move electrode slowly in the direction of travel, maintaining correct arc length, bead width, and electrode angle.

Note: The bead should penetrate the plate, but not go through the plate to cause burn through.

☐ 9. Stop just as you reach the end of the plate and start letting off on the foot control.

☐ 10. Let off on foot control and keep torch in place for a few seconds after end of the weld.

☐ 11. Place torch in a secure, safe place.

☐ 12. Secure plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 13. Have your instructor check your work.

☐ 14. Continue making passes as directed by your instructor.

☐ 15. Visually inspect each pass and have your instructor check your work.

☐ 16. Shut down equipment as previously outlined.

☐ 17. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 6—Strike and Maintain an Arc to make Stringer Beads on Mild or Stainless Steel With Filler Metal in the Flat Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

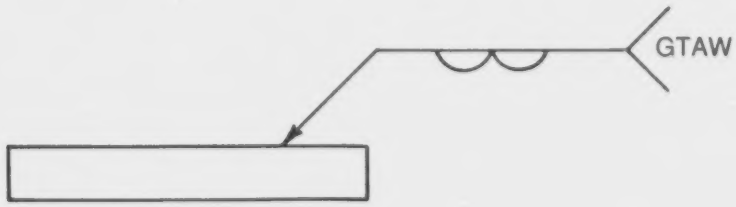
Evaluation criteria	Rating
Equipment setup and safety	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Stinger bead quality	_____

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Mild or stainless steel as selected by instructor
Wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



2. Filler metal: Mild or stainless steel per instructor

Job Sheet 6

3. Tungsten: 1-2% thoriated
4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: Flat
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

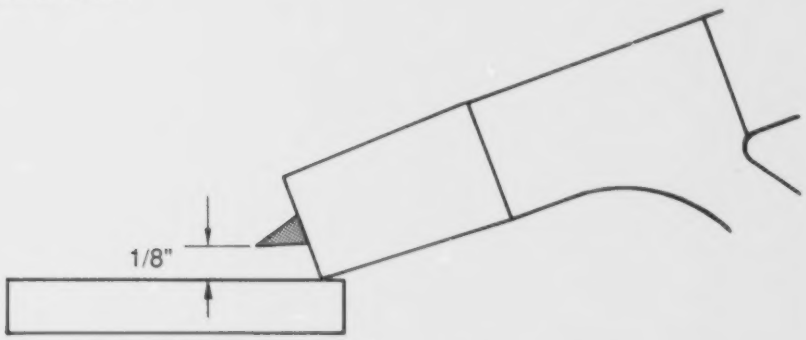
C. Procedure

☐ 1. Set up equipment as previously outlined.

☐ 2. Double check electrode extension and shielding gas flow rate.

☐ 3. Position plate in accordance with specifications, and hold torch with right hand, if right handed, or opposite if left handed.

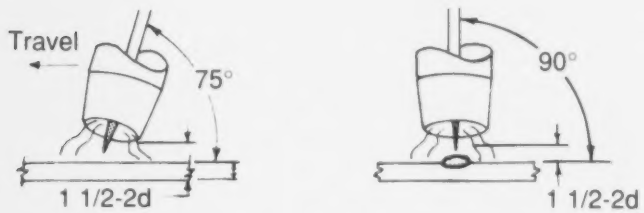
☐ 4. Move torch so that nozzle rests on base metal with electrode about ⅛" off base metal.



☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

Job Sheet 6

☐ 6. Correct electrode angle the moment the arc is established.

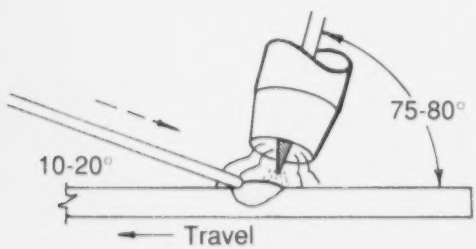


Side View Front View

Courtesy Lincoln Electric Company

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



Side View

Courtesy Lincoln Electric Company

☐ 9. Withdraw filler rod about ½" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

Job Sheet 6

- ☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.
- ☐ 14. Have your instructor check your work.
- ☐ 15. Continue making passes as directed by your instructor.
- ☐ 16. Visually inspect each pass and have your instructor check your work.
- ☐ 17. Shut down equipment as previously outlined.
- ☐ 18. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 7—Weld to Specifications a Fillet Weld Lap Joint on Mild or Stainless Steel in the Flat Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

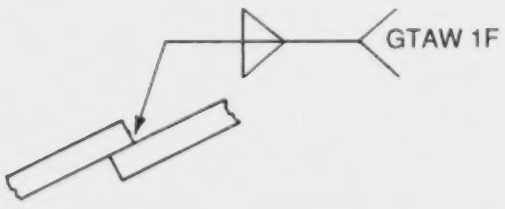
Evaluation criteria	Rating
Equipment setup and safety	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Weld quality	_____

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Mild or stainless steel as selected by instructor
Wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



2. Filler metal: Mild or stainless steel per instructor

Job Sheet 7

3. Tungsten: 1-2% thoriated
4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: 1F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

C. Procedure

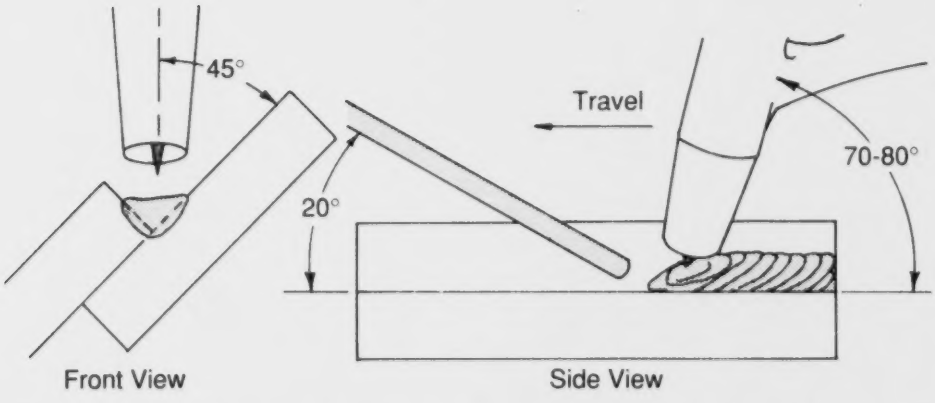
☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Tack weld plates on both ends for specified joint.

☐ 3. Position plate in accordance with specifications.

☐ 4. Lower welding hood and depress foot control until the arc jumps the gap and is established.

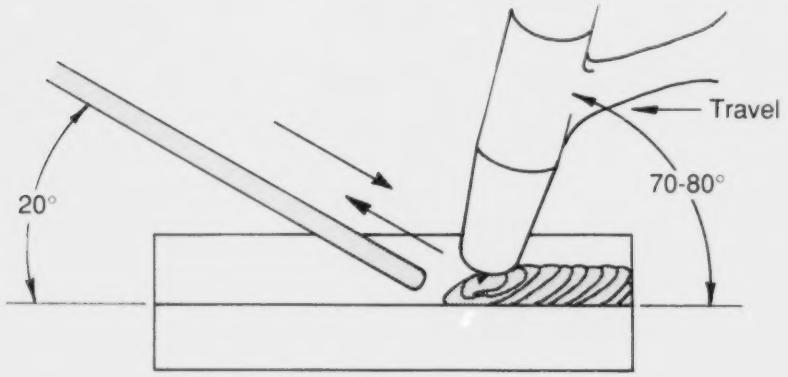
☐ 5. Correct electrode angle the moment the arc is established.



☐ 6. Preheat the starting point until a small molten puddle is formed.

Job Sheet 7

☐ 7. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



Side View

☐ 8. Withdraw filler rod about ½" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 9. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 10. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 11. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 12. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 13. Have your instructor check your work.

☐ 14. Continue making passes as directed by your instructor.

☐ 15. Visually inspect each pass and have your instructor check your work.

☐ 16. Repeat procedure for other side of joint, if required and have your instructor check your work.

Job Sheet 7

☐ 17. Shut down equipment as previously outlined.

☐ 18. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 8—Weld to Specifications a Fillet Weld T-Joint on Mild or Stainless Steel in the Flat Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

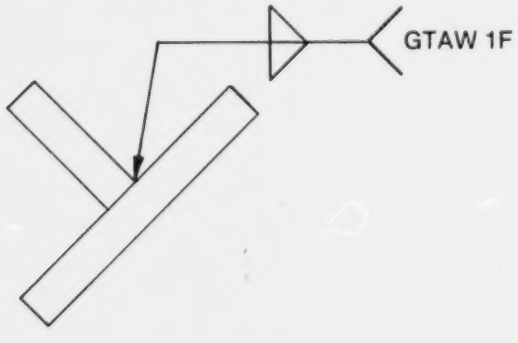
Evaluation criteria	Rating
Equipment setup and safety	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Weld quality	_____

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Mild or stainless steel as selected by instructor
Wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



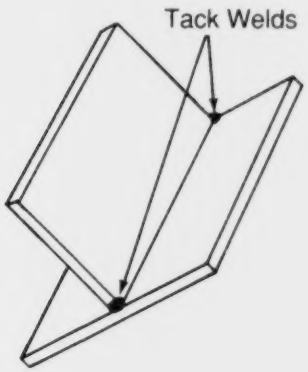
Job Sheet 8

2. Filler metal: Mild or stainless steel per instructor
3. Tungsten: 1-2% thoriated
4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: 1F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

C. Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Tack weld plates on both ends for specified joint.



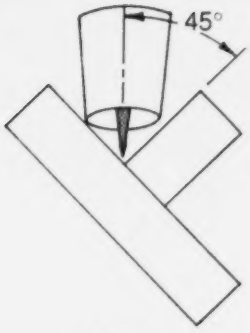
☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about ⅛" off base metal.

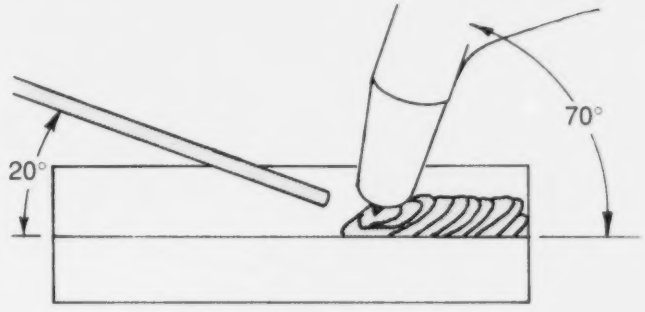
☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

Job Sheet 8

☐ 6. Correct electrode angle the moment the arc is established.



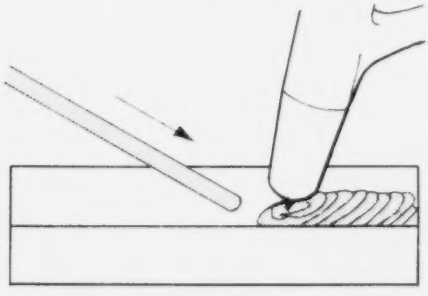
Front View



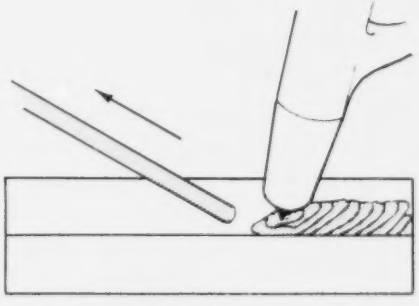
Side View

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



Side View



Side View

☐ 9. Withdraw filler rod about ½" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

Job Sheet 8

- ☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.
- ☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.
- ☐ 14. Have your instructor check your work.
- ☐ 15. Continue making passes as directed by your instructor.
- ☐ 16. Visually inspect each pass and have your instructor check your work.
- ☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.
- ☐ 18. Shut down equipment as previously outlined.
- ☐ 19. Check in tools and materials and clean area.

Evaluator's comments: _____

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_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 9—Weld to Specifications an Open-Root Square-Groove Butt Joint on Mild or Stainless Steel in the Flat Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

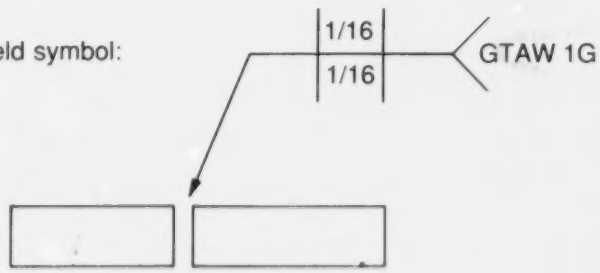
Evaluation criteria	Rating
Equipment setup and safety	_____
Use of gap wire and supports	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Grinding root preparation	_____
Weld quality	_____

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Mild or stainless steel as selected by instructor
Wire brush, pliers, and portable grinder
1/16" gap wire with support plates
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



Job Sheet 9

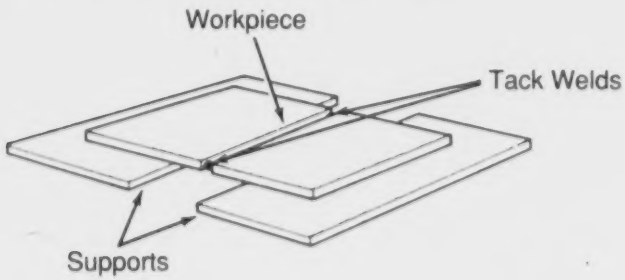
2. Filler metal: Mild or stainless steel per instructor
3. Tungsten: 1-2% thoriated
4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: 1G
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

C. Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Use a 1/16" gap wire and place the plates into position and tack weld both ends.

☐ 3. Position plate in accordance with specifications.

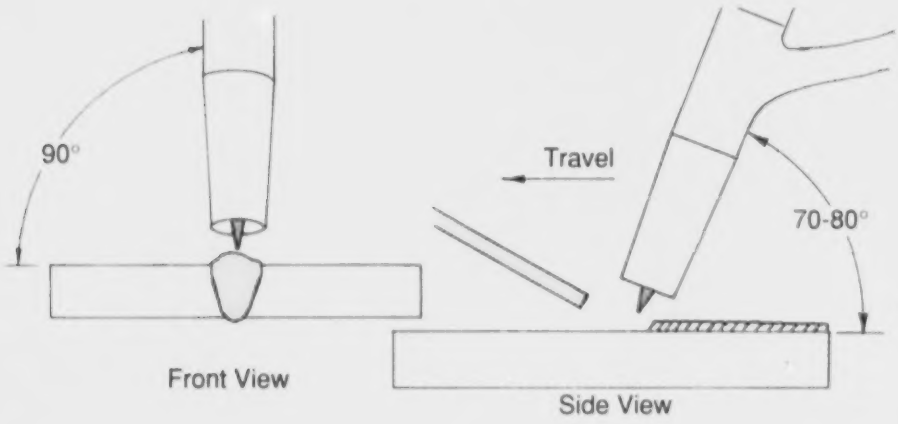


☐ 4. Move torch so that nozzle rests on base metal with electrode about 1/8" off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

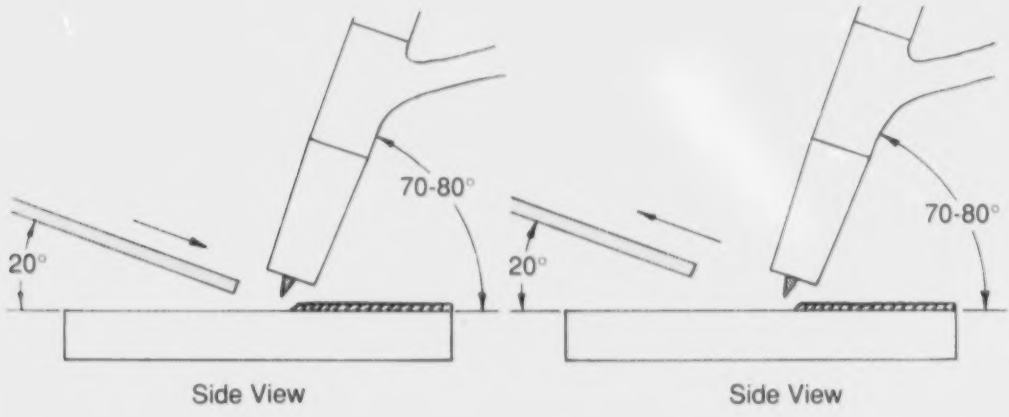
Job Sheet 8

☐ 6. Correct electrode angle the moment the arc is established.



☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



☐ 9. Withdraw filler rod about ½" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

Job Sheet 9

- ☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.
- ☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.
- ☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.
- ☐ 14. Have your instructor check your work.
- ☐ 15. Continue making passes as directed by your instructor.
- ☐ 16. Visually inspect each pass and have your instructor check your work.
- ☐ 17. Grind out root side of joint prior to welding other side.
- ☐ 18. Weld other side of joint, if directed by your instructor.
- ☐ 19. Have your instructor check your work.
- ☐ 20. Shut down equipment as previously outlined.
- ☐ 21. Check in tools and materials and clean area.

Evaluator's comments: _____

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GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 10—Weld to Specifications a Fillet Weld Lap Joint on Mild or Stainless Steel in the Horizontal Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

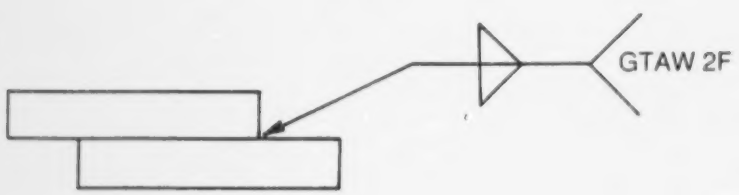
Evaluation criteria	Rating
Equipment setup and safety	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Weld quality	_____

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Mild or stainless steel as selected by instructor
Wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



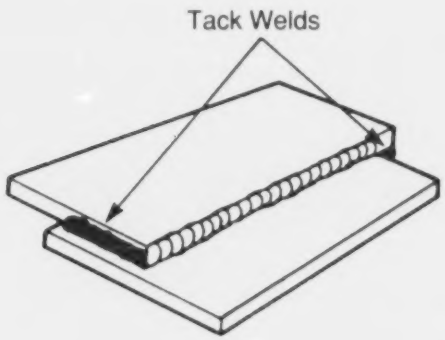
Job Sheet 10

2. Filler metal: Mild or stainless steel per instructor
3. Tungsten: 1-2% thoriated
4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: 2F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

C. Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Place plates in correct joint position and tack weld both ends.



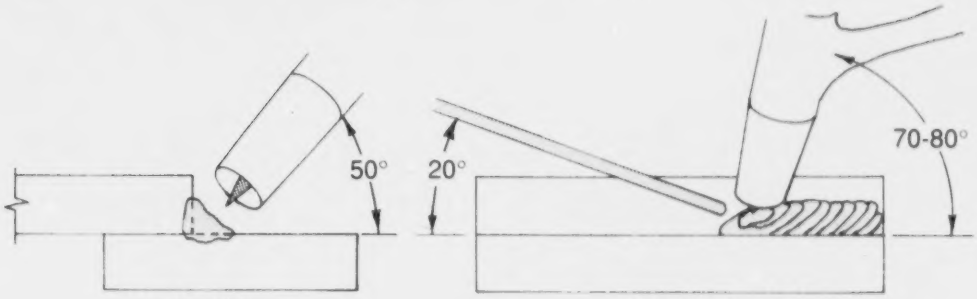
☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about ⅛" off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

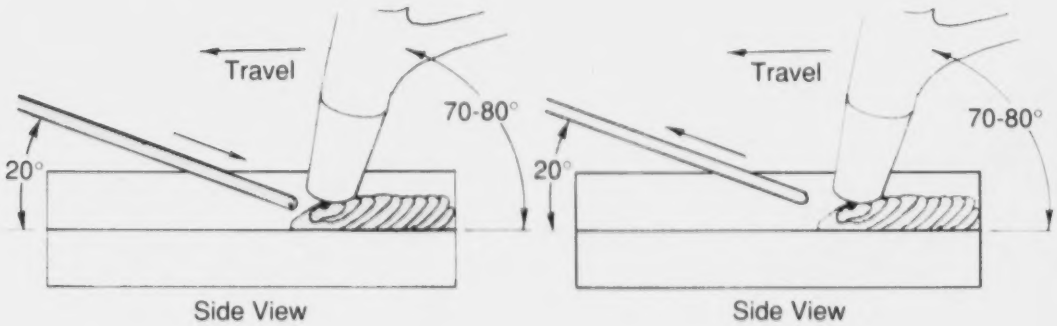
Job Sheet 10

☐ 6. Correct electrode angle the moment the arc is established.



☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



☐ 9. Withdraw filler rod about ½" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

Job Sheet 10

- ☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.
- ☐ 14. Have your instructor check your work.
- ☐ 15. Continue making passes as directed by your instructor.
- ☐ 16. Visually inspect each pass and have your instructor check your work.
- ☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.
- ☐ 18. Shut down equipment as previously outlined.
- ☐ 19. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 11—Weld to Specifications a Fillet Weld T-Joint on Mild or Stainless Steel in the Horizontal Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

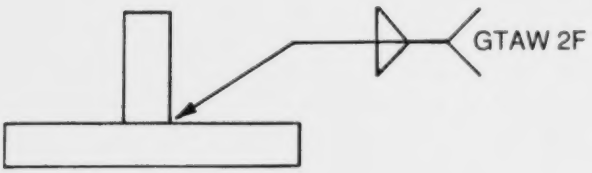
Evaluation criteria	Rating
Equipment setup and safety	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Weld quality	_____

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Mild or stainless steel as selected by instructor
Wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



Job Sheet 11

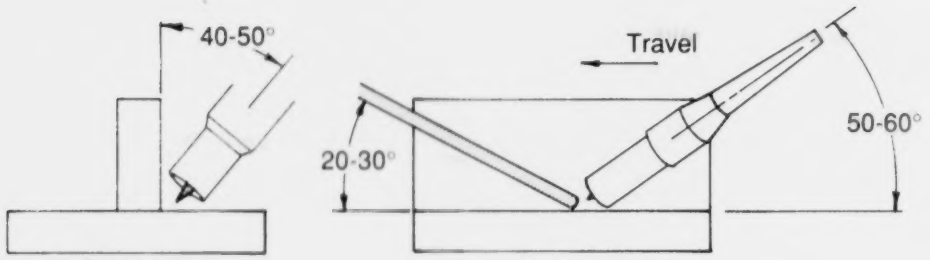
2. Filler metal: Mild or stainless steel per instructor
3. Tungsten: 1-2% thoriated
4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: 2F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

C. Procedure

- ☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.
- ☐ 2. Place plates in correct joint position and tack weld both ends.
- ☐ 3. Position plate in accordance with specifications.
- ☐ 4. Move torch so that nozzle rests on base metal with electrode about ⅛" off base metal.
- ☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

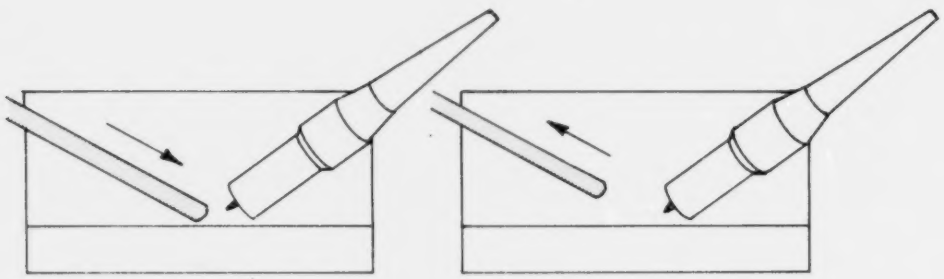
Job Sheet 11

☐ 6. Correct electrode angle the moment the arc is established.



☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



Side View

☐ 9. Withdraw filler rod about ½" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

Job Sheet 11

- ☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.
- ☐ 14. Have your instructor check your work.
- ☐ 15. Continue making passes as directed by your instructor.
- ☐ 16. Visually inspect each pass and have your instructor check your work.
- ☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.
- ☐ 18. Shut down equipment as previously outlined.
- ☐ 19. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 12—Weld to Specifications a Fillet Weld Lap Joint on Mild or Stainless Steel in the Vertical Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

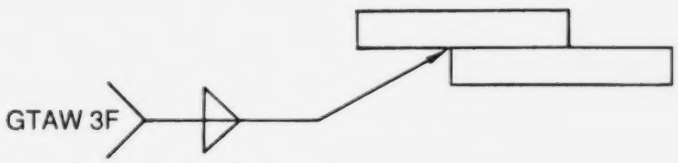
Evaluation criteria	Rating
Equipment setup and safety	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Weld quality	_____

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Mild or stainless steel as selected by instructor
Wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



Top View

Job Sheet 12

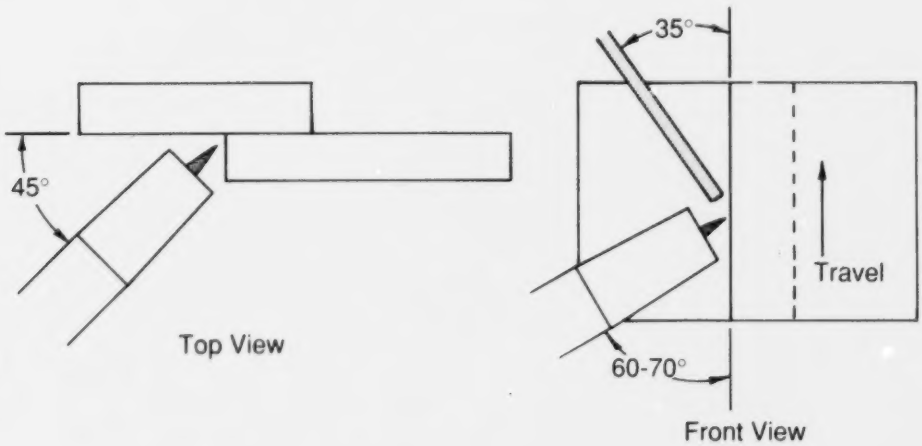
2. Filler metal: Mild or stainless steel per instructor
3. Tungsten: 1-2% thoriated
4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: 3F
7. Direction of welding: Vertical up
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

C. Procedure

- ☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.
- ☐ 2. Place plates in correct joint position and tack weld both ends.
- ☐ 3. Position plate in accordance with specifications.
- ☐ 4. Move torch so that nozzle rests on base metal with electrode about ⅛" off base metal.
- ☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

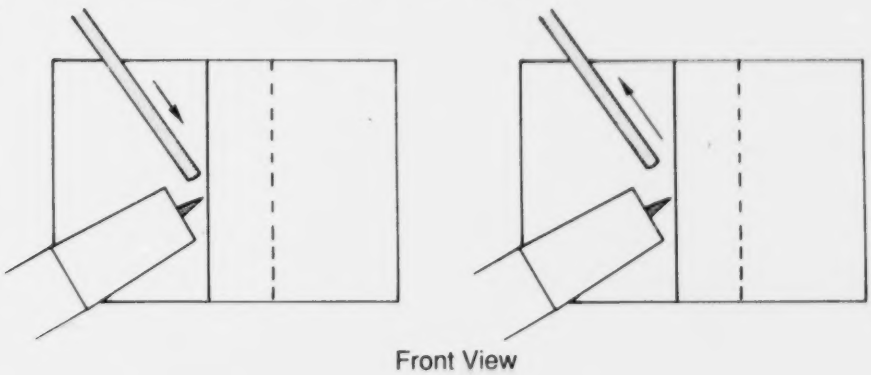
Job Sheet 12

☐ 6. Correct electrode angle the moment the arc is established.



☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



☐ 9. Withdraw filler rod about ½" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

Job Sheet 12

- ☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.
- ☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.
- ☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.
- ☐ 14. Have your instructor check your work.
- ☐ 15. Continue making passes as directed by your instructor.
- ☐ 16. Visually inspect each pass and have your instructor check your work.
- ☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.
- ☐ 18. Shut down equipment as previously outlined.
- ☐ 19. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

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GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 13—Weld to Specifications a Fillet Weld T-Joint on Mild or Stainless Steel in the Vertical Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

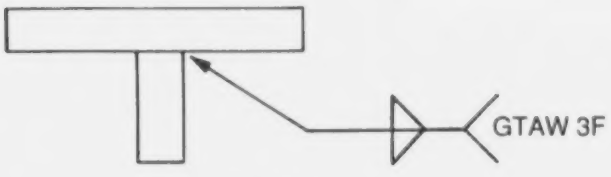
Evaluation criteria	Rating
Equipment setup and safety	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Weld quality	_____

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Mild or stainless steel as selected by instructor
Wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



Top View

Job Sheet 13

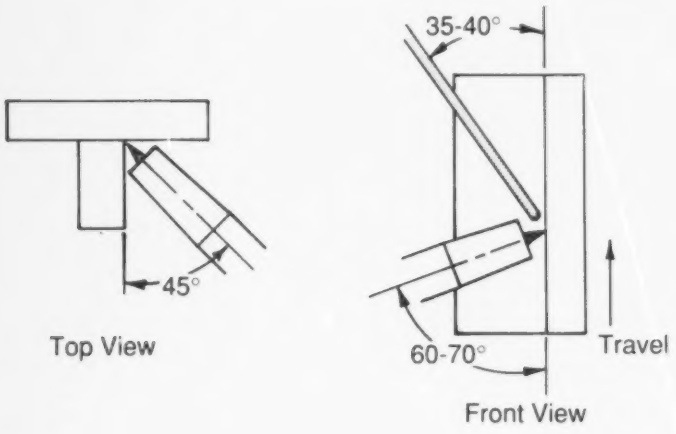
2. Filler metal: Mild or stainless steel per instructor
3. Tungsten: 1-2% thoriated
4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: 3F
7. Direction of welding: Vertical up
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

C. Procedure

- ☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.
- ☐ 2. Place plates in correct joint position and tack weld both ends.
- ☐ 3. Position plate in accordance with specifications.
- ☐ 4. Move torch so that nozzle rests on base metal with electrode about ⅛" off base metal.
- ☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

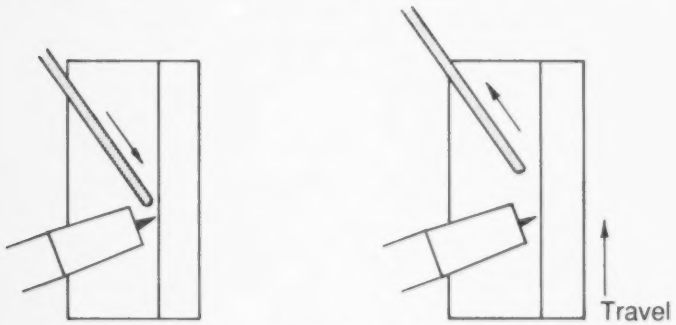
Job Sheet 13

☐ 6. Correct electrode angle the moment the arc is established.



☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



☐ 9. Withdraw filler rod about ½" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

Job Sheet 13

- ☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.
- ☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.
- ☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.
- ☐ 14. Have your instructor check your work.
- ☐ 15. Continue making passes as directed by your instructor.
- ☐ 16. Visually inspect each pass and have your instructor check your work.
- ☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.
- ☐ 18. Shut down equipment as previously outlined.
- ☐ 19. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 14—Weld to Specifications an Open-Root Square-Groove Butt Joint on Mild or Stainless Steel in the Vertical Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

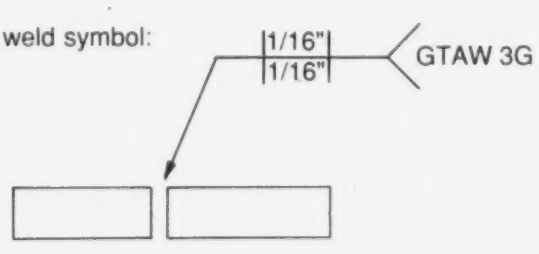
Evaluation criteria	Rating
Equipment setup and safety	_____
Use of gap wire and supports	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Grinding root preparation	_____
Weld quality	_____

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Mild or stainless steel as selected by instructor
Wire brush, pliers, and portable grinder
1/16" gap wire
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



Job Sheet 14

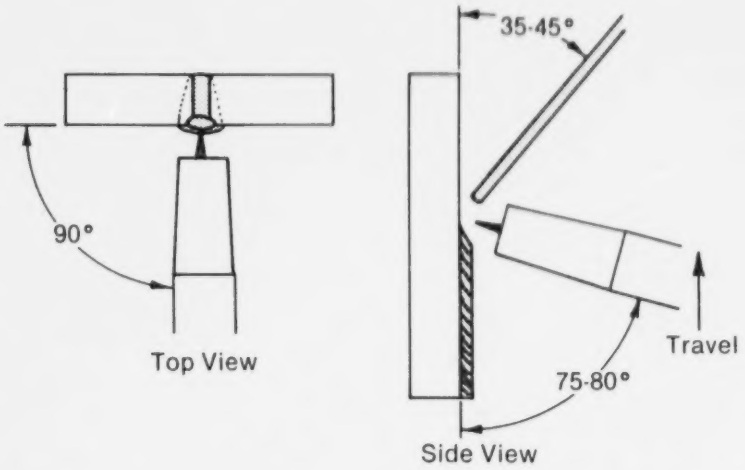
2. Filler metal: Mild or stainless steel per instructor
3. Tungsten: 1-2% thoriated
4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: 3G
7. Direction of welding: Vertical up
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

C. Procedure

- ☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.
- ☐ 2. Use a 1/16" gap wire and place the plates into position and tack weld both ends.
- ☐ 3. Position plate in accordance with specifications.
- ☐ 4. Move torch so that nozzle rests on base metal with electrode about 1/8" off base metal.
- ☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

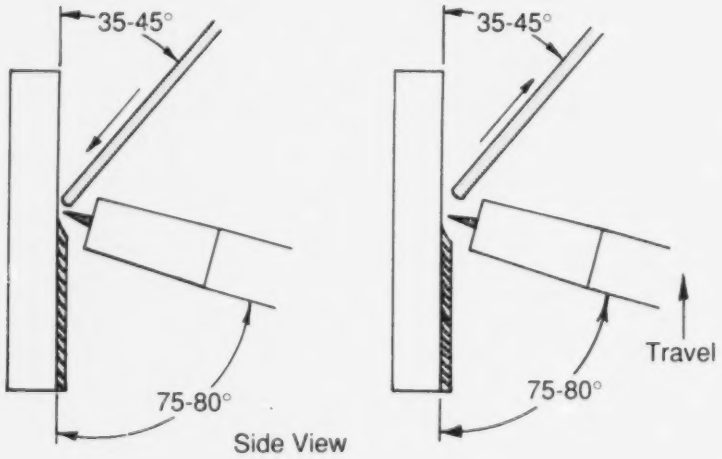
Job Sheet 14

☐ 6. Correct electrode angle the moment the arc is established.



☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



☐ 9. Withdraw filler rod about ½" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

Job Sheet 14

- ☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.
- ☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.
- ☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.
- ☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.
- ☐ 14. Have your instructor check your work.
- ☐ 15. Continue making passes as directed by your instructor.
- ☐ 16. Visually inspect each pass and have your instructor check your work.
- ☐ 17. Grind out root side of joint prior to welding other side.
- ☐ 18. Weld other side of joint, if directed by your instructor.
- ☐ 19. Have your instructor check your work.
- ☐ 20. Shut down equipment as previously outlined.
- ☐ 21. Check in tools and materials and clean area.

Evaluator's comments: _____

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_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 15—Weld to Specifications a Fillet Weld Lap Joint on Mild or Stainless Steel in the Overhead Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

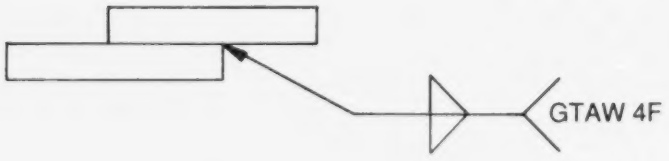
Evaluation criteria	Rating
Equipment setup and safety	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Weld quality	_____

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Mild or stainless steel as selected by instructor
Wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



Job Sheet 15

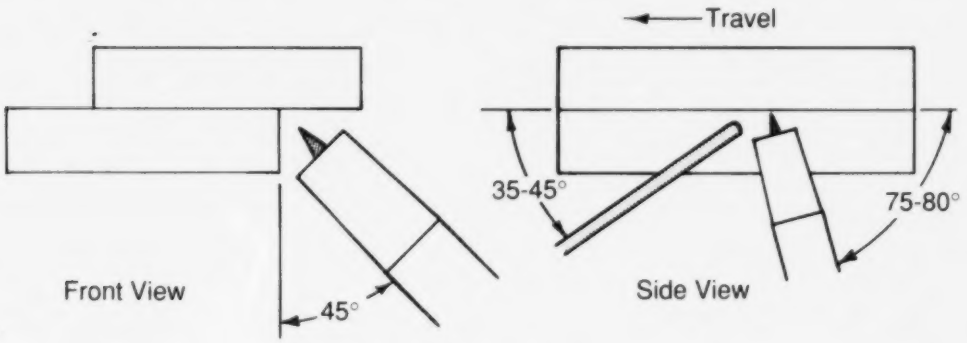
2. Filler metal: Mild or stainless steel per instructor
3. Tungsten: 1-2% thoriated
4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: 4F
7. Direction of welding: Vertical up
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

C. Procedure

- ☐ 1. Set up equipment as previously outlined.
- ☐ 2. Check with your instructor about electrode extension and flow rate setting because overhead welding sometimes requires adjustment to flow rate and extension.
- ☐ 3. Place plates in correct joint position and tack weld both ends.
- ☐ 4. Position plate in accordance with specifications.
- ☐ 5. Move torch so that nozzle rests on base metal with electrode about ⅛" off base metal.
- ☐ 6. Lower welding hood and depress foot control until the arc jumps the gap and is established.

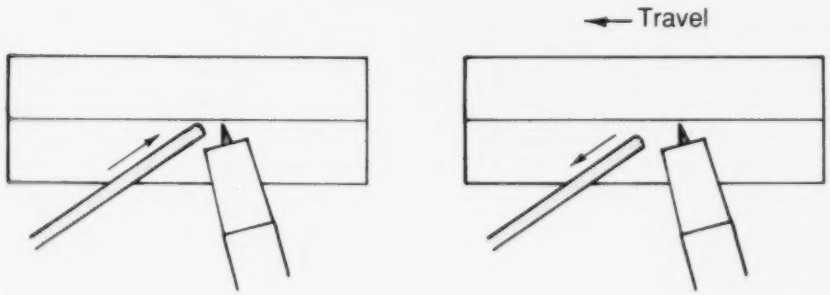
Job Sheet 15

☐ 7. Correct electrode angle the moment the arc is established.



☐ 8. Preheat the starting point until a small molten puddle is formed.

☐ 9. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



Side View

☐ 10. Withdraw filler rod about ½" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 11. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

Job Sheet 15

- ☐ 12. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.
- ☐ 13. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.
- ☐ 14. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.
- ☐ 15. Have your instructor check your work.
- ☐ 16. Continue making passes as directed by your instructor.
- ☐ 17. Visually inspect each pass and have your instructor check your work.
- ☐ 18. Repeat procedure for other side of joint, if required and have your instructor check your work.
- ☐ 19. Shut down equipment as previously outlined.
- ☐ 20. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 16—Weld to Specifications a Fillet Weld T-Joint on Mild or Stainless Steel in the Overhead Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

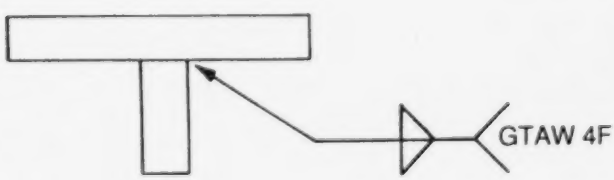
Evaluation criteria	Rating
Equipment setup and safety	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Weld quality	_____

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Mild or stainless steel as selected by instructor
Wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



Job Sheet 16

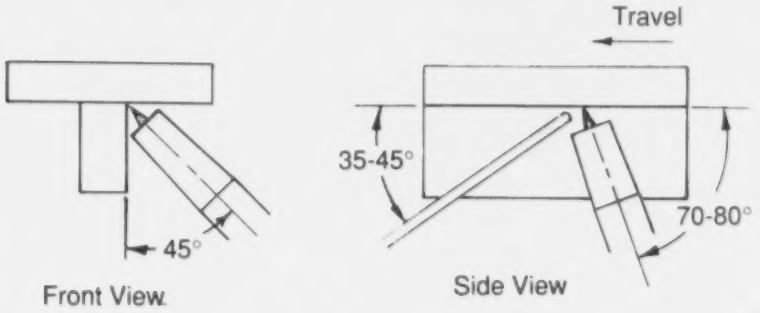
2. Filler metal: Mild or stainless steel per instructor
3. Tungsten: 1-2% thoriated
4. Shielding gas: Ar or He
5. Electrical: DCEN high frequency set on start only
6. Position: 4F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: N/A
10. Testing: Visual

C. Procedure

- ☐ 1. Set up equipment as previously outlined.
- ☐ 2. Check with your instructor about electrode extension and flow rate setting because overhead welding sometimes requires adjustment to flow rate and extension.
- ☐ 3. Place plates in correct joint position and tack weld both ends.
- ☐ 4. Position plate in accordance with specifications.
- ☐ 5. Move torch so that nozzle rests on base metal with electrode about ⅛" off base metal.
- ☐ 6. Lower welding hood and depress foot control until the arc jumps the gap and is established.

Job Sheet 16

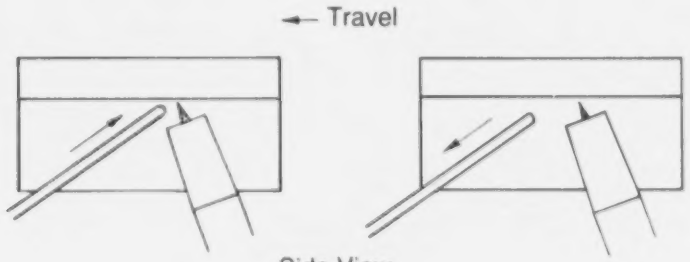
☐ 7. Correct electrode angle the moment the arc is established.



Front View Side View

☐ 8. Preheat the starting point until a small molten puddle is formed.

☐ 9. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



Side View

☐ 10. Withdraw filler rod about ½" from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 11. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 12. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 13. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

Job Sheet 16

- ☐ 14. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.
- ☐ 15. Have your instructor check your work.
- ☐ 16. Continue making passes as directed by your instructor.
- ☐ 17. Visually inspect each pass and have your instructor check your work.
- ☐ 18. Repeat procedure for other side of joint, if required and have your instructor check your work.
- ☐ 19. Shut down equipment as previously outlined.
- ☐ 20. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 17—Set Up and Shut Down GTAW Equipment for Welding Aluminum

Name _____ Attempt Number _____

Date _____ Overall Rating _____

Evaluation criteria	Rating
Setup and machine settings	_____
Flow meter setting	_____
Coolant system check	_____
Tungsten electrode preparation	_____
Shut down safety	_____

A. Tools and materials

GTAW machine with accessories
Shielding gas as selected by instructor
Pure or zirconiated tungsten electrode
Coolant
Brass ground clamp
Safety clothing and safety glasses

B. Procedure

☐ 1. Set up power supply.

☐ 2. Set current range selector according to metal thickness.

☐ 3. Set current switch to AC.

☐ 4. Set weld control switch to GTAW.

☐ 5. Set high frequency switch to CONTINUOUS position.

☐ 6. Set spark control for soft start to avoid burn through on thin metal.

☐ 7. Set remote control switch for contactor or amperage control to either REMOTE or PANEL depending on machine accessories.

Job Sheet 17

- ☐ 8. Set post flow timer according to electrode size.
- ☐ 9. Turn on cylinder valve and adjust flow meter regulator to rate of flow recommended for electrode.
- ☐ 10. Check for proper and complete circulation in the cooling system and verify that there are no leaks.
- ☐ 11. Select correct size collet and gas nozzle according to electrode size.
- ☐ 12. Prepare the tungsten electrode with a ball tip (see Job Sheet 19).
- ☐ 13. Adjust the electrode extension to no more than ⅛".
- ☐ 14. Connect ground clamp to base metal.
- ☐ 15. Switch machine on.
- ☐ 16. Have your instructor check results of your setup procedure.
- ☐ 17. Prepare for shutdown.
- ☐ 18. Close gas cylinder valve.
- ☐ 19. Depress foot control to bleed gas line.
- ☐ 20. Shut off flow meter regulator.
- ☐ 21. Turn off cooling system.
- ☐ 22. Turn off power switch.
- ☐ 23. Remove electrode from torch and return to proper storage.
- ☐ 24. Remove collet and gas nozzle and return to proper storage.
- ☐ 25. Disconnect ground clamp.
- ☐ 26. Roll cables up neatly and clean up work station.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 18—Prepare Aluminum for GTAW

Name _____ Attempt Number _____

Date _____ Overall Rating _____

Evaluation criteria	Rating
Scale removal	_____
Edge preparation	_____
Oxide removal	_____
Cleaning and drying	_____

A. Tools and materials

Aluminum as selected by instructor
Portable grinder with sanding attachment
Stainless steel brush and file
Clamps or vise
Degreasing/deoxidizer solution
Clean shop rags
Safety clothing, safety glasses, and face shield

B. Procedure

- ☐ 1. Secure workpiece with clamps or vise.
- ☐ 2. Remove all mill scale, dirt, and paint from all surfaces with portable sander.
- ☐ 3. Grind or file edges of joint for specified edge preparation.
- ☐ 4. Remove surface oxide with stainless steel brush.
- ☐ 5. Wet a shop rag with cleaning solution and wipe plate to remove any oxide residue.
- ☐ 6. Wipe plate dry with clean shop rag.
- ☐ 7. Have your instructor check your work.

Job Sheet 18

☐ 8. Store in a dry place and weld as soon as possible after cleaning.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 19—Prepare a Tungsten Electrode for Welding Aluminum

Name _____ Attempt Number _____

Date _____ Overall Rating _____

Evaluation criteria	Rating
Setup and machine settings	_____
Ball preparation on electrode	_____
Electrode contamination free	_____
Shut down safety	_____

A. Tools and materials

GTAW machine with accessories
Shielding gas as selected by instructor
Tungsten electrode, pure or zirconiated
Thick copper block
Pliers
Safety clothing and safety glasses
Grinding wheel (optional)

B. Procedure

☐ 1. Set up GTAW equipment as previously outlined.

☐ 2. Switch machine to DCRP (DCEP).

☐ 3. Place electrode in torch.

☐ 4. Position copper block on work table and ground it.

☐ 5. Turn power on.

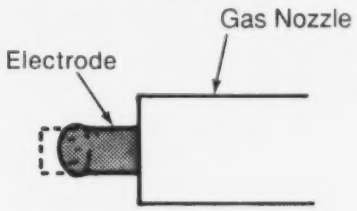
☐ 6. Move torch down with electrode held perpendicular to the copper block until electrode tip is about ⅛" from the copper block.

☐ 7. Depress foot control to cause arc to jump the gap between electrode tip and copper block.

Job Sheet 19

☐ 8. Allow end of tungsten to turn bright red, but be careful not to contaminate the tungsten by touching the copper block.

☐ 9. Allow electrode tip to form a ball equal to or slightly larger than the diameter of the electrode.



☐ 10. Increase amperage by depressing foot control slightly if the ball is too small.

☐ 11. Continue heating until desired diameter is obtained, then release foot pedal and raise torch and electrode from the block.

Caution: The size of the ball should not exceed 1½ times the electrode diameter or it will become molten and drop off during welding.

☐ 12. Inspect ball for correct diameter and a bright, shiny appearance.

☐ 13. Inspect for discoloration and contamination, and if the tip is purple or black, it indicates post flow of shielding gas is inadequate for the diameter of the electrode and flow should be increased.

☐ 14. Break improper ball off with a pair of pliers and repeat the procedure and inspect.

Note: Larger tungsten electrodes should be tapered before you put a ball on the end. Your instructor may direct you to taper a larger electrode and repeat the procedure for placing a ball on the end.

☐ 15. Have your instructor check your work.

☐ 16. Shut down equipment as previously outlined.

☐ 17. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 20—Strike and Maintain an Arc to make Stringer Beads on Aluminum Without Filler Metal in the Flat Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

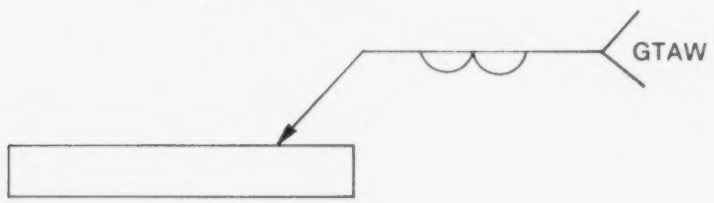
Evaluation criteria	Rating
Equipment setup and machine adjustments	_____
Electrode preparation	_____
Shielding gas adjustment	_____
Stinger bead quality	_____

A. Tools and materials

GTAW machine with accessories
Aluminum as selected by instructor
Tungsten electrode to specifications
Shielding gas to specifications
Stainless steel wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



2. Filler metal: N/A

3. Tungsten: Pure or zirconiated

Job Sheet 20

4. Shielding gas: Ar or He
5. Electrical: AC, high frequency continuous
6. Position: Flat
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

C. Procedure

☐ 1. Set up equipment as previously outlined.

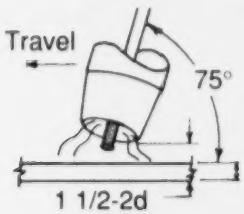
☐ 2. Double check electrode extension and shielding gas flow rate.

☐ 3. Position plate in accordance with specifications, and hold torch with right hand, if right handed, or opposite if left handed.

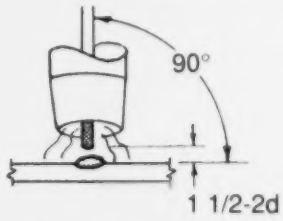
☐ 4. Move torch so that nozzle rests on base metal with electrode about ⅛" off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.



Side View



Front View

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move electrode slowly in the direction of travel, maintaining correct arc length, bead width, and electrode angle.

Note: The bead should penetrate the plate, but not go through the plate to cause burn through.

Job Sheet 20

- ☐ 9. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of the weld.
- ☐ 11. Place torch in a secure, safe place.
- ☐ 12. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.
- ☐ 13. Have your instructor check your work.
- ☐ 14. Continue making passes as directed by your instructor.
- ☐ 15. Visually inspect each pass and have your instructor check your work.
- ☐ 16. Shut down equipment as previously outlined.
- ☐ 17. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 21—Strike and Maintain an Arc to make Stringer Beads on Aluminum With Filler Metal in the Flat Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

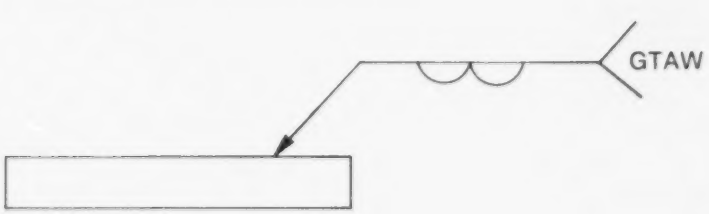
Evaluation criteria	Rating
Equipment setup and machine adjustments	_____
Electrode preparation	_____
Shielding gas adjustment	_____
Filler metal application	_____
Stinger bead quality	_____

A. Tools and materials

GTAW machine with accessories
Aluminum as selected by instructor
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Stainless steel wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



2. Filler metal: Mild or stainless steel per instructor

Job Sheet 21

3. Tungsten: Pure or zirconiated
4. Shielding gas: Ar or He
5. Electrical: AC, high frequency continuous
6. Position: Flat
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

C. Procedure

☐ 1. Set up equipment as previously outlined.

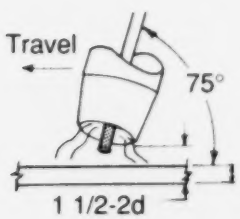
☐ 2. Double check electrode extension and shielding gas flow rate.

☐ 3. Position plate in accordance with specifications, and hold torch with right hand, if right handed, or opposite if left handed.

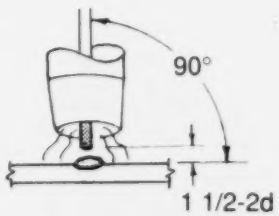
☐ 4. Move torch so that nozzle rests on base metal with electrode about ⅛ off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.



Side View

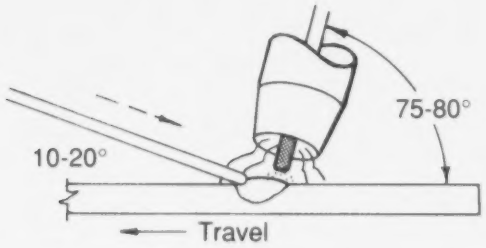


Front View

☐ 7. Preheat the starting point until a small molten puddle is formed.

Job Sheet 21

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



Side View

☐ 9. Withdraw filler rod about ½ from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Shut down equipment as previously outlined.

☐ 18. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 22—Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Flat Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

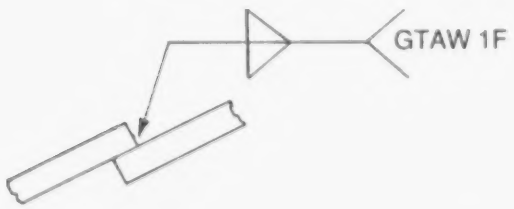
Evaluation criteria	Rating
Equipment setup and safety	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Weld quality	_____

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Aluminum as selected by instructor
Stainless steel wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



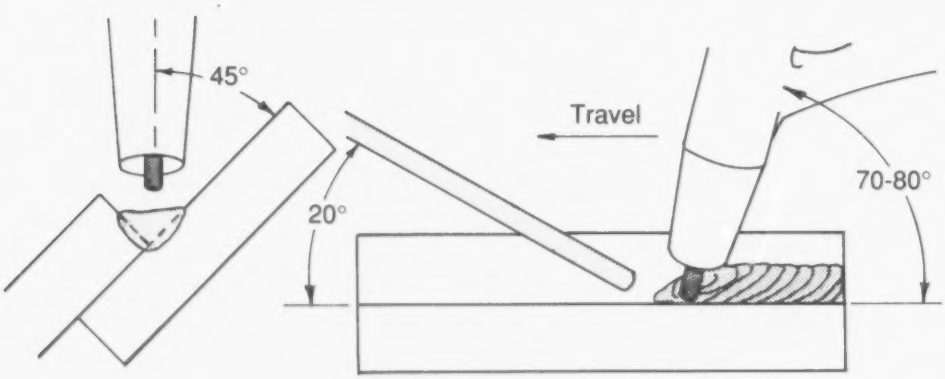
2. Filler metal: Aluminum per instructor

Job Sheet 22

3. Tungsten: Pure zirconiated
4. Shielding gas: Ar or He
5. Electrical: AC, high frequency continuous
6. Position: 1F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

C. Procedure

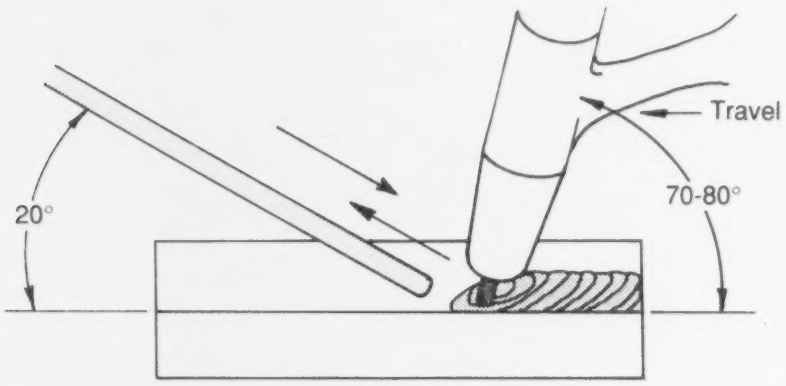
- ☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.
- ☐ 2. Place plates in correct joint position and tack weld both ends.
- ☐ 3. Position plate in accordance with specifications.
- ☐ 4. Move torch so that nozzle rests on base metal with electrode about ⅛" off base metal.
- ☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.
- ☐ 6. Correct electrode angle the moment the arc is established.



Job Sheet 22

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



Side View

☐ 9. Withdraw filler rod about ½ from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

Job Sheet 22

- ☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.
- ☐ 18. Shut down equipment as previously outlined.
- ☐ 19. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 23—Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Flat Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

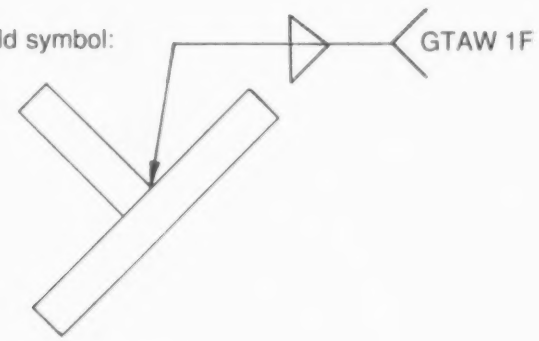
Evaluation criteria	Rating
Equipment setup and safety	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Weld quality	_____

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Aluminum as selected by instructor
Stainless steel wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



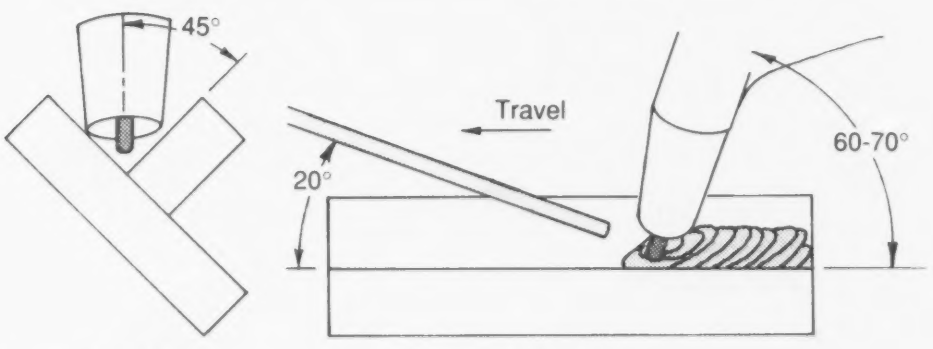
2. Filler metal: Aluminum per instructor

Job Sheet 23

3. Tungsten: Pure or zirconiated
4. Shielding gas: Ar or He
5. Electrical: AC, high frequency set on continuous
6. Position: 1F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

C. Procedure

- ☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.
- ☐ 2. Place plates in correct joint position and tack weld both ends.
- ☐ 3. Position plate in accordance with specifications.
- ☐ 4. Move torch so that nozzle rests on base metal with electrode about ⅛″ off base metal.
- ☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.
- ☐ 6. Correct electrode angle the moment the arc is established.

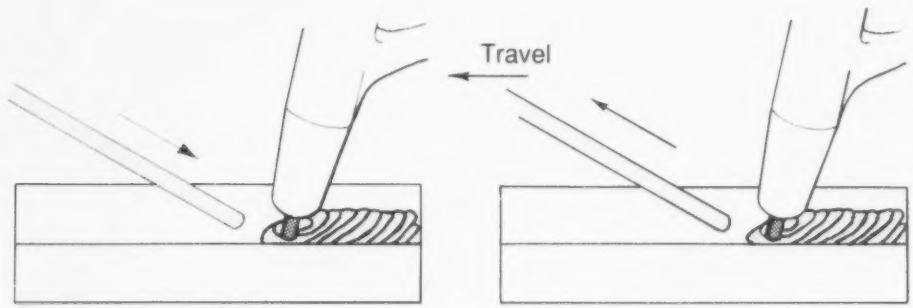


Front View Side View

Job Sheet 23

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



Side View Side View

☐ 9. Withdraw filler rod about ½ from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

Note: Allow for heat build-up by increasing travel speed or letting up on the foot pedal to decrease amperage.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

Job Sheet 23

- ☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.
- ☐ 18. Shut down equipment as previously outlined.
- ☐ 19. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 24—Weld to Specifications a Square-Groove Butt Joint on Aluminum in the Flat Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

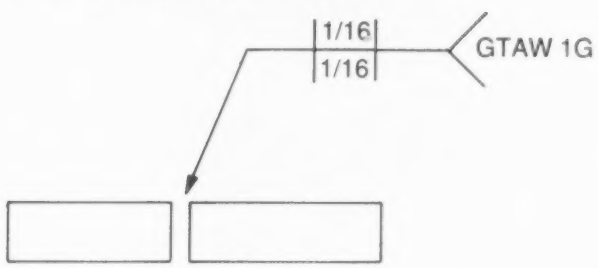
Evaluation criteria	Rating
Equipment setup and safety	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Weld quality	_____

A. Tools and materials

GTAW machine with accessories
Grinder with aluminum grinding disk
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Aluminum as selected by instructor
Stainless steel wire brush and pliers
Safety clothing and safety glasses
1/16" gap wire with support plates

B. Specifications

1. Joint design and weld symbol:

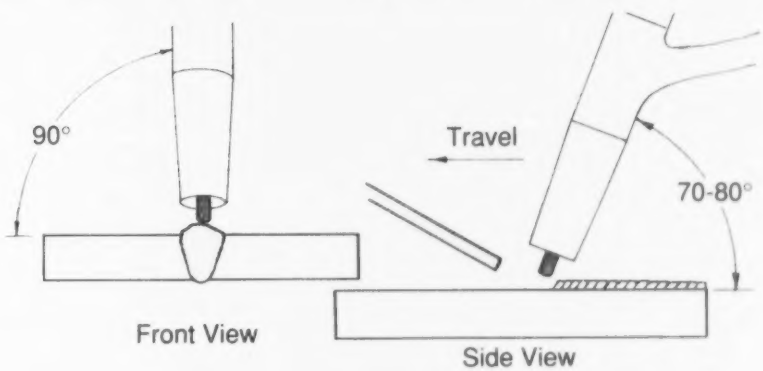


Job Sheet 24

2. Filler metal: Aluminum per instructor
3. Tungsten: Pure or zirconiated
4. Shielding gas: Ar or He
5. Electrical: AC, high frequency set on continuous
6. Position: 1G
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

C. Procedure

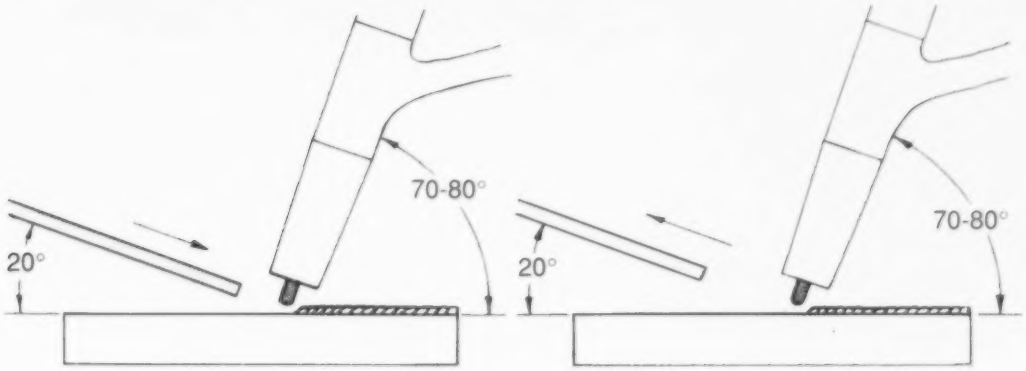
- ☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.
- ☐ 2. Place plates in correct joint position and tack weld both ends.
- ☐ 3. Position plate in accordance with specifications.
- ☐ 4. Move torch so that nozzle rests on base metal with electrode about ⅛" off base metal.
- ☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.
- ☐ 6. Correct electrode angle the moment the arc is established.



Job Sheet 24

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



Side View Side View

☐ 9. Withdraw filler rod about ½ from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

Note: Allow for heat build-up by increasing travel speed or letting up on the foot pedal to decrease amperage.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

Job Sheet 24

- ☐ 17. Grind out root side of joint prior to welding other side.
- ☐ 18. Weld other side of joint, if directed, and have your instructor check your work.
- ☐ 19. Shut down equipment as previously outlined.
- ☐ 20. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 25—Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Horizontal Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

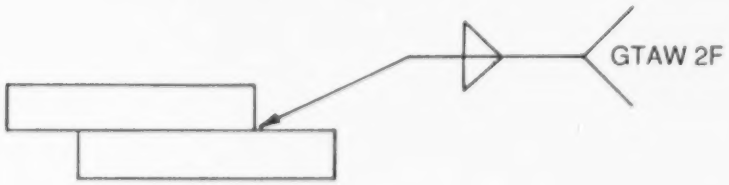
Evaluation criteria	Rating
Equipment setup and safety	
Electrode extension	
Shielding gas adjustment	
Filler metal application	
Weld quality	

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Aluminum as selected by instructor
Stainless steel wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



2. Filler metal: Aluminum per instructor

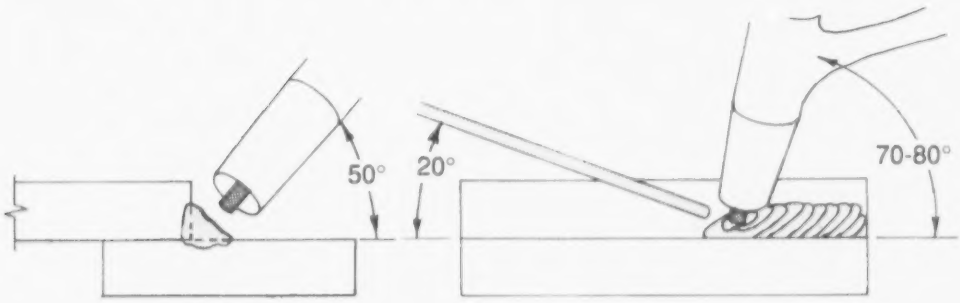
3. Tungsten: Pure or zirconiated

Job Sheet 25

4. Shielding gas: Ar or He
5. Electrical: AC, high frequency set on continuous
6. Position: 2F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

C. Procedure

- ☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.
- ☐ 2. Place plates in correct joint position and tack weld both ends.
- ☐ 3. Position plate in accordance with specifications.
- ☐ 4. Move torch so that nozzle rests on base metal with electrode about ⅛″ off base metal.
- ☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.
- ☐ 6. Correct electrode angle the moment the arc is established.

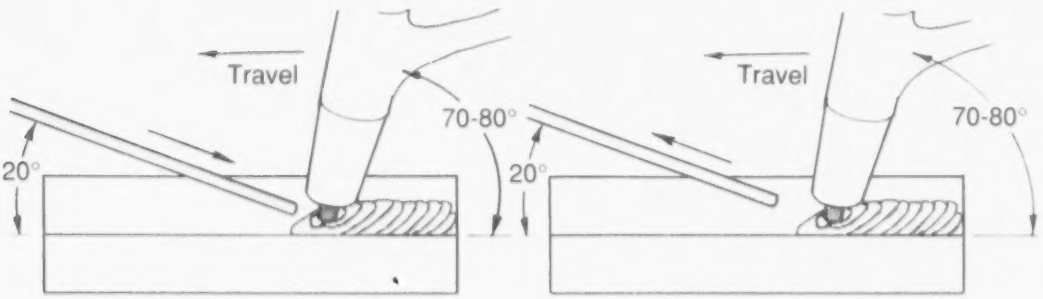


Front View Side View

Job Sheet 25

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



Side View Side View

☐ 9. Withdraw filler rod about ½ from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

Note: Allow for heat build-up by increasing travel speed or letting up on the foot pedal to decrease amperage.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

Job Sheet 25

- ☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.
- ☐ 18. Shut down equipment as previously outlined.
- ☐ 19. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 26—Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Horizontal Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

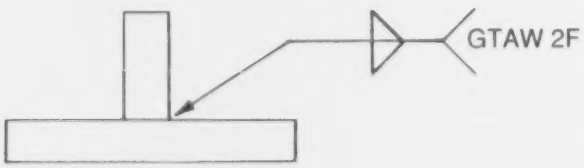
Evaluation criteria	Rating
Equipment setup and safety	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Weld quality	_____

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Aluminum as selected by instructor
Stainless steel wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



2. Filler metal: Aluminum per instructor

Job Sheet 26

3. Tungsten: Pure or zirconiated
4. Shielding gas: Ar or He
5. Electrical: AC, high frequency set on continuous
6. Position: 2F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

C. Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

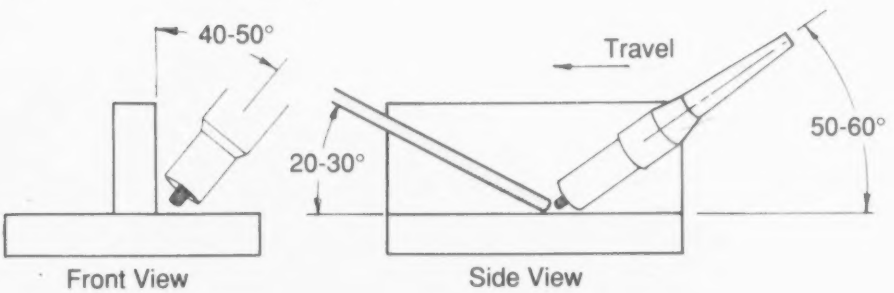
☐ 2. Place plates in correct joint position and tack weld both ends.

☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about ⅛″ off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

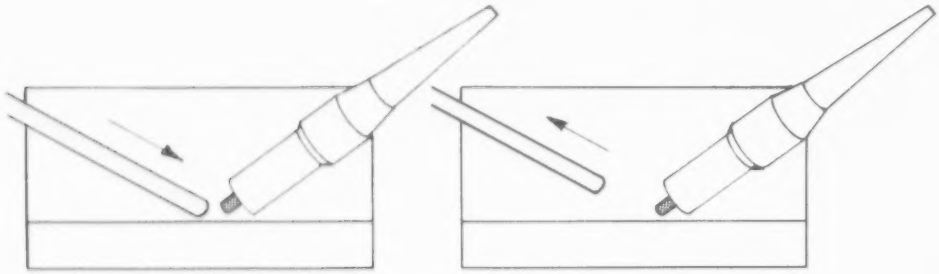
☐ 6. Correct electrode angle the moment the arc is established.



☐ 7. Preheat the starting point until a small molten puddle is formed.

Job Sheet 26

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



Side View

☐ 9. Withdraw filler rod about ½ from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

Note: Allow for heat build-up by increasing travel speed or letting up on the foot pedal to decrease amperage.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.

Job Sheet 26

☐ 18. Shut down equipment as previously outlined.

☐ 19. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 27—Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Vertical Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

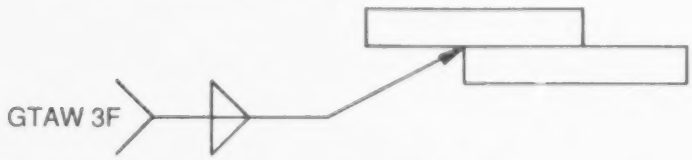
Evaluation criteria	Rating
Equipment setup and safety	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Weld quality	_____

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Aluminum as selected by instructor
Stainless steel wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



Top View

2. Filler metal: Aluminum per instructor

Job Sheet 27

3. Tungsten: Pure or zirconiated
4. Shielding gas: Ar or He
5. Electrical: AC, high frequency set on continuous
6. Position: 3F
7. Direction of welding: Vertical Up
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

C. Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

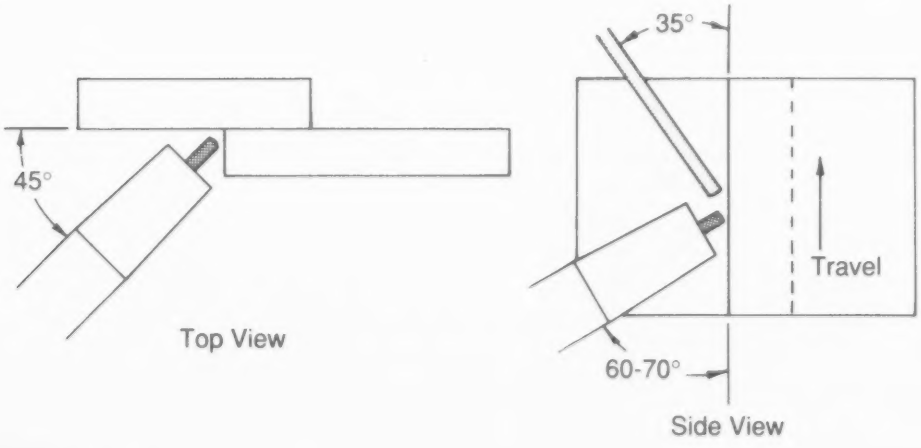
☐ 2. Place plates in correct joint position and tack weld both ends.

☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about ⅛" off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

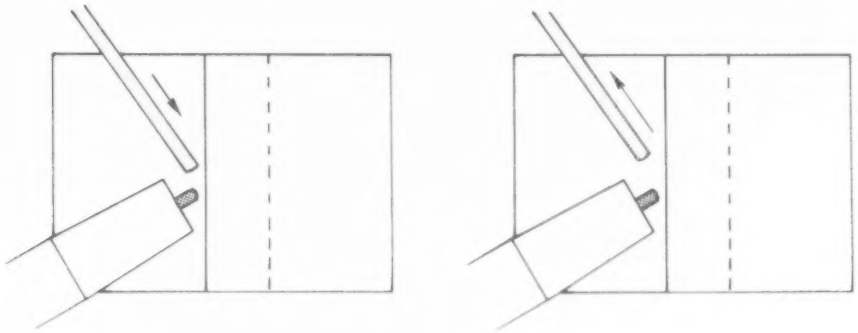
☐ 6. Correct electrode angle the moment the arc is established.



Job Sheet 27

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



Side View

☐ 9. Withdraw filler rod about ½ from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

Note: Allow for heat build-up by increasing travel speed or letting up on the foot pedal to decrease amperage.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

Job Sheet 27

- ☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.
- ☐ 18. Shut down equipment as previously outlined.
- ☐ 19. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 28—Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Vertical Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

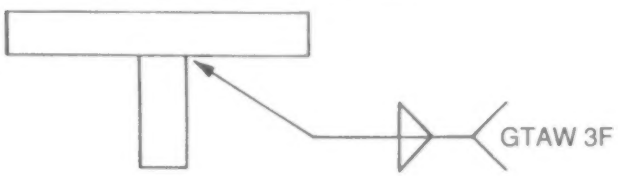
Evaluation criteria	Rating
Equipment setup and safety	
Electrode extension	
Shielding gas adjustment	
Filler metal application	
Weld quality	

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Aluminum as selected by instructor
Stainless steel wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



Top View

2. Filler metal: Aluminum per instructor

Job Sheet 28

3. Tungsten: Pure or zirconiated
4. Shielding gas: Ar or He
5. Electrical: AC, high frequency set on continuous
6. Position: 3F
7. Direction of welding: Vertical Up
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

C. Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

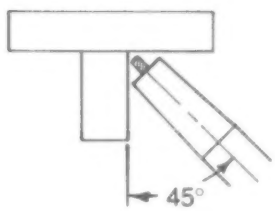
☐ 2. Place plates in correct joint position and tack weld both ends.

☐ 3. Position plate in accordance with specifications.

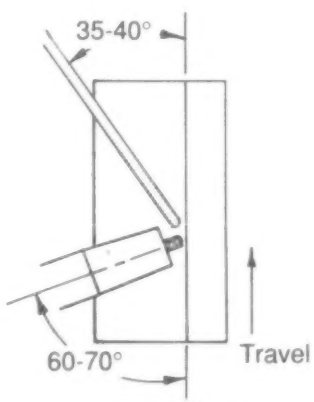
☐ 4. Move torch so that nozzle rests on base metal with electrode about ⅛″ off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 6. Correct electrode angle the moment the arc is established.



Top View

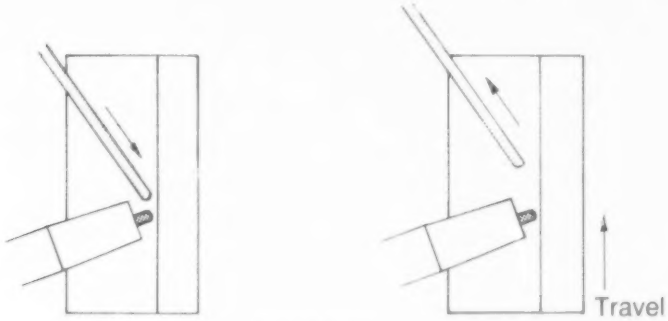


Front View

Job Sheet 28

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



Front View

☐ 9. Withdraw filler rod about ½ from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

Note: Allow for heat build-up by increasing travel speed or letting up on the foot pedal to decrease amperage.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

☐ 15. Continue making passes as directed by your instructor.

☐ 16. Visually inspect each pass and have your instructor check your work.

Job Sheet 28

- ☐ 17. Repeat procedure for other side of joint, if required and have your instructor check your work.
- ☐ 18. Shut down equipment as previously outlined.
- ☐ 19. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 29—Weld to Specifications a Square-Groove Butt Joint on Aluminum in the Vertical Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

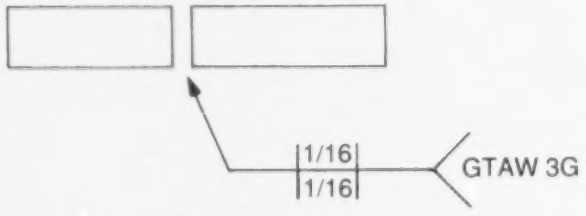
Evaluation criteria	Rating
Equipment setup and safety	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Weld quality	_____

A. Tools and materials

GTAW machine with accessories
Grinder with aluminum grinding disk
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Aluminum as selected by instructor
Stainless steel wire brush and pliers
Safety clothing and safety glasses
1/16" gap wire

B. Specifications

1. Joint design and weld symbol:



Top View

2. Filler metal: Aluminum per instructor

Job Sheet 29

3. Tungsten: Pure or zirconiated
4. Shielding gas: Ar or He
5. Electrical: AC, high frequency set on continuous
6. Position: 3G
7. Direction of welding: Vertical Up
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

C. Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

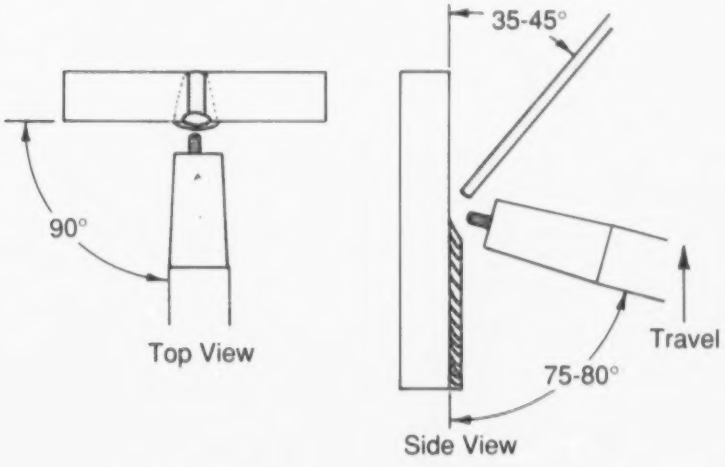
☐ 2. Place plates in correct joint position and tack weld both ends.

☐ 3. Position plate in accordance with specifications.

☐ 4. Move torch so that nozzle rests on base metal with electrode about ⅛" off base metal.

☐ 5. Lower welding hood and depress foot control until the arc jumps the gap and is established.

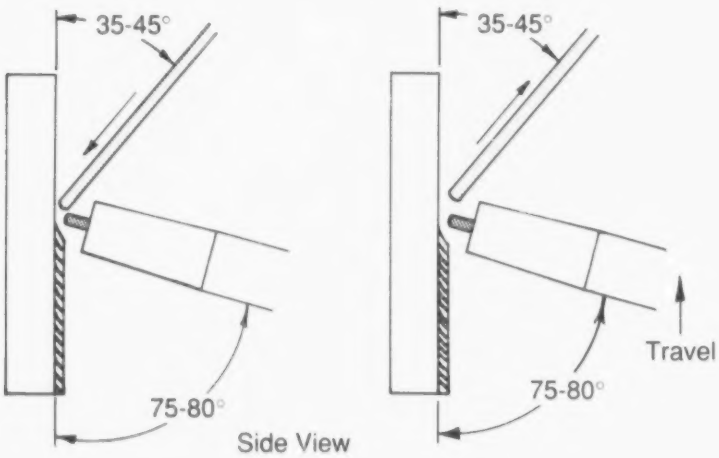
☐ 6. Correct electrode angle the moment the arc is established.



Job Sheet 29

☐ 7. Preheat the starting point until a small molten puddle is formed.

☐ 8. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



☐ 9. Withdraw filler rod about ½ from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 10. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 11. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

Note: Allow for heat build-up by increasing travel speed or letting up on the foot pedal to decrease amperage.

☐ 12. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 13. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 14. Have your instructor check your work.

Job Sheet 29

- ☐ 15. Continue making passes as directed by your instructor.
- ☐ 16. Visually inspect each pass and have your instructor check your work.
- ☐ 17. Grind out root side of joint prior to welding other side.
- ☐ 18. Repeat procedure for other side of joint, if required and have your instructor check your work.
- ☐ 19. Shut down equipment as previously outlined.
- ☐ 20. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 30—Weld to Specifications a Fillet Weld Lap Joint on Aluminum in the Overhead Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

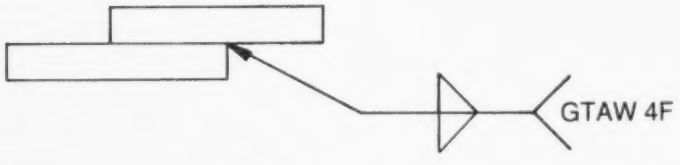
Evaluation criteria	Rating
Equipment setup and safety	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Weld quality	_____

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Aluminum as selected by instructor
Stainless steel wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



2. Filler metal: Aluminum per instructor

Job Sheet 30

3. Tungsten: Pure or zirconiated
4. Shielding gas: Ar or He
5. Electrical: AC, high frequency set on continuous
6. Position: 4F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

C. Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Check with your instructor about electrode extension and flow rate setting because overhead welding sometimes requires adjustment to flow rate and extension.

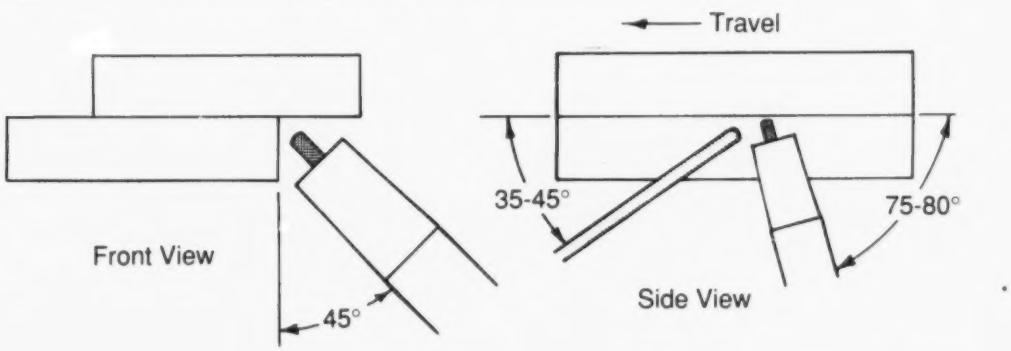
☐ 3. Place plates in correct joint position and tack weld both ends.

☐ 4. Position plate in accordance with specifications.

☐ 5. Move torch so that nozzle rests on base metal with electrode about ⅛″ off base metal.

☐ 6. Lower welding hood and depress foot control until the arc jumps the gap and is established.

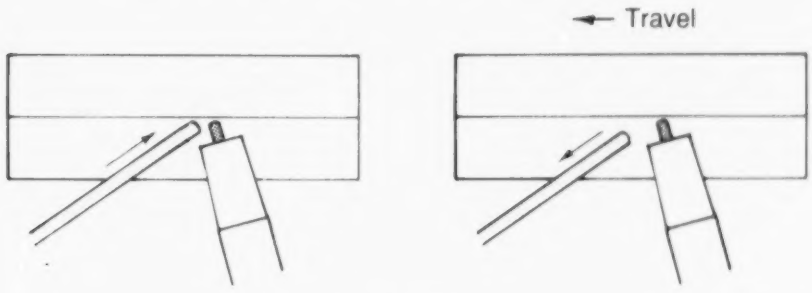
☐ 7. Correct electrode angle the moment the arc is established.



Job Sheet 30

☐ 8. Preheat the starting point until a small molten puddle is formed.

☐ 9. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



Side View

☐ 10. Withdraw filler rod about ½ from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 11. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 12. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 13. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 14. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 15. Have your instructor check your work.

☐ 16. Continue making passes as directed by your instructor.

☐ 17. Visually inspect each pass and have your instructor check your work.

☐ 18. Repeat procedure for other side of joint, if required and have your instructor check your work.

Job Sheet 30

☐ 19. Shut down equipment as previously outlined.

☐ 20. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____

GTAW Equipment, Applications, and Techniques
Unit 2

Job Sheet 31—Weld to Specifications a Fillet Weld T-Joint on Aluminum in the Overhead Position

Name _____ Attempt Number _____

Date _____ Overall Rating _____

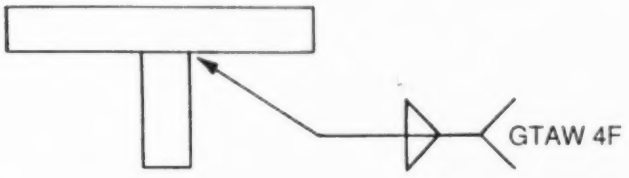
Evaluation criteria	Rating
Equipment setup and safety	_____
Electrode extension	_____
Shielding gas adjustment	_____
Filler metal application	_____
Weld quality	_____

A. Tools and materials

GTAW machine with accessories
Tungsten electrode to specifications
Shielding gas to specifications
Filler metal as selected by instructor
Aluminum as selected by instructor
Stainless steel wire brush and pliers
Safety clothing and safety glasses

B. Specifications

1. Joint design and weld symbol:



2. Filler metal: Aluminum per instructor

Job Sheet 31

3. Tungsten: Pure or zirconiated
4. Shielding gas: Ar or He
5. Electrical: AC, high frequency set on continuous
6. Position: 4F
7. Direction of welding: N/A
8. Technique: Steady forward motion
9. Cleaning: Stainless steel brush
10. Testing: Visual

C. Procedure

☐ 1. Set up equipment as previously outlined; check electrode extension and flow rate.

☐ 2. Check with your instructor about electrode extension and flow rate setting because overhead welding sometimes requires adjustment to flow rate and extension.

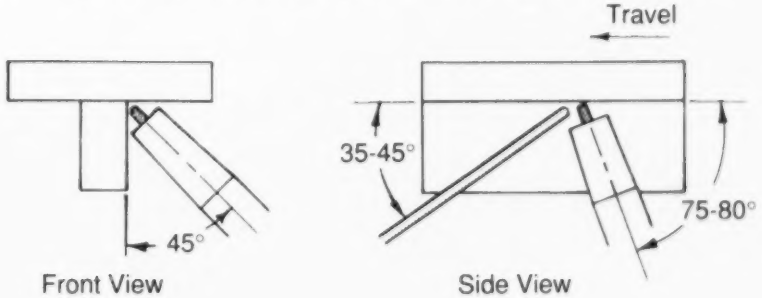
☐ 3. Place plates in correct joint position and tack weld both ends.

☐ 4. Position plate in accordance with specifications.

☐ 5. Move torch so that nozzle rests on base metal with electrode about ⅛" off base metal.

☐ 6. Lower welding hood and depress foot control until the arc jumps the gap and is established.

☐ 7. Correct electrode angle the moment the arc is established.

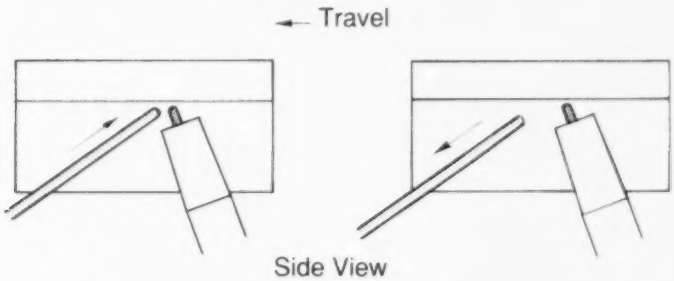


Front View Side View

Job Sheet 31

☐ 8. Preheat the starting point until a small molten puddle is formed.

☐ 9. Move filler rod into the leading edge of the molten puddle and let a drop or two of molten filler metal fill the puddle.



Side View

☐ 10. Withdraw filler rod about ½ from the arc so the torch and puddle can be moved in the direction of travel, but be sure to keep the end of the rod in the shielded zone.

☐ 11. Advance the puddle forward while using the torch to maintain a uniform bead width and then reinsert the filler rod into the center of the molten puddle at the point of the arc and let a drop or two of molten filler metal fill the puddle.

☐ 12. Repeat procedure of inserting and withdrawing the filler rod, moving the torch, then reinserting filler rod until stringer is completed.

☐ 13. Stop just as you reach the end of the plate and start letting off on the foot control, then let off on foot control and keep torch in place for a few seconds after end of weld.

☐ 14. Hold plate with pliers and visually inspect for good penetration with no burn through, uniform bead width with neat appearance, and even bead ripples.

☐ 15. Have your instructor check your work.

☐ 16. Continue making passes as directed by your instructor.

☐ 17. Visually inspect each pass and have your instructor check your work.

☐ 18. Repeat procedure for other side of joint, if required and have your instructor check your work.

☐ 19. Shut down equipment as previously outlined.

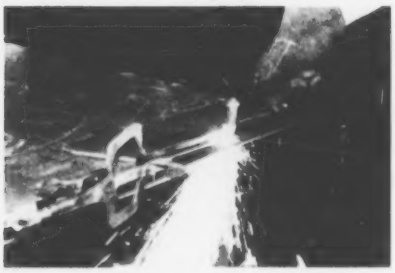
Job Sheet 31

☐ 20. Check in tools and materials and clean area.

Evaluator's comments: _____

_____

_____



Plasma Arc Cutting
Unit 3

Objective Sheet

Unit Objective

After completing this unit, the student should be able to prepare a PAC machine for operation and use a PAC system to make a contact cut, a stand-off cut, and to gouge mild steel. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to plasma arc cutting with their correct definitions.
2. Complete statements about basic characteristics of plasma arc cutting.
3. Match basic components with their functions in an air cut PAC system.
4. Select true statements about plasma arc electrical safety.
5. Complete statements about plasma arc environmental safety.
6. Solve problems about plasma arc workplace safety.
7. Select true statements about advantages of plasma arc cutting.
8. Select true statements about characteristics of plasma arc transfer modes.
9. Solve problems about guidelines for PAC electrode selection.
10. Select true statements about guidelines for cutting nozzle selection and installation.
11. Solve problems about shielding cups, their design and uses.
12. Select true statements about plasma air and secondary air used with PAC.
13. Solve problems about PAC consumables, their characteristics and maintenance.

Objective Sheet

14. Solve problems about PAC system duty cycles.
15. Select true statements about guidelines for setting PAC flow rate and flow pressure.
16. Solve problems about guidelines for using compressed air with a PAC system.
17. Select true statements about factors affecting cutting speeds.
18. Select true statements about techniques for contact and stand-off cutting.
19. Select true statements about techniques for cutting expanded metal.
20. Solve problems about techniques for gouging metal.
21. Select true statements about techniques for piercing and beveling metal.
22. Match cutting faults with their probable causes.
23. Prepare a PAC machine for operation. (Job Sheet 1)
24. Complete a contact cut on selected metal. (Job Sheet 2)
25. Complete a stand-off cut on selected metal. (Job Sheet 3)
26. Gouge mild steel plate with a PAC unit. (Job Sheet 4)

Plasma Arc Cutting
Unit 3

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for enrichment of exceptional students as well as accommodation of special needs students.
4. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.
10. Discuss the job sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of the written test. Add or modify test items as needed.
13. Give written test.
14. Compile job sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignments.
15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Use Objective 2 to illustrate the concept of the fourth state of matter and how high energy plasma functions in the plasma arc cutting process. Skill areas: **foundation skills** and **science**.

2. Modify Objective 3 as required to reflect components of the system students will actually be working with. The unit presents three different PAC systems, but other systems may have component variations. Skill area: **learning to learn**.

3. Objectives 4, 5, and 6 require special attention because they concern safety. With a PAC system, safety requirements exceed those of other welding/cutting processes. The noise factor is especially important because even low amperage systems which may modify noise to a degree are still noisy enough to contribute to hearing problems for those exposed to the noise for extended periods of time. Fumes are another problem with PAC. Impress students with all the parameters of PAC safety, not just electrical safety requirement. Skill area: **learning to learn**.

4. When discussing nozzle selection in Objective 10, discuss the structure of the nozzle and the important part it plays in swirling the gas around the electrode to accelerate the ionization process. Also note that some manufacturers use a "swirl" ring as a torch component to further accelerate ionization. Skill areas: **foundation skills** and **science**.

5. Stress the importance of clean, dry, oil-free air when using compressed shop air with a dual-flow PAC system. Demonstrate how to purge or clean the sediment bowl during the setup procedure for cutting. Skill area: **learning to learn**.

6. Demonstrate gouging, piercing, and beveling. If students have time, permit them to practice piercing and beveling as part of Job Sheet 4. Skill area: **learning to learn**.

7. Find a nearby industry that is using a PAC mechanized water system for component cutting. Arrange for an industry operator to talk to the class about the system. If time and conditions permit, take class members to the industry so they can observe a PAC water system in operation. Skill area: **learning to learn**.

Suggested Activities

Resources Used in Developing This Unit

1. O'Brien, R. L., ed. *Welding Handbook Eighth Edition, Vol. 2, Welding Processes.* Miami, FL: American Welding Society, 1991.

2. *1988/89 Welding & Fabrication Data Handbook.* Cleveland OH: Penton Publishing, Inc., 1988.

3. *A History of Plasma Cutting Milestones in the Development of a New Technology.* Hanover, NH: Hypertherm, Inc., 1991.

4. *Smith Plasma Cutting Systems Owners Manual for SPC50A, SPC80A, and SPC120A-4.* Watertown, SD: Smith Equipment, Division of Tescom Corporation, undated.

5. *Instruction Manual for the Thermal Arc® PAK® 5XR™.* St. Louis, MO: Thermal Dynamics Corporation, 1987.

Suggested Supplemental Resources

Recommended Practices for Plasma Arc Cutting is a basic process reference that is also an American National Standard. Available from:

The American Welding Society
550 LeJeune Road
P.O. Box 351040
Miami, FL 33135
1-800-334-9353

Instructions For Evaluating Student Performance

When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure.

Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Suggested Activities

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Plasma Arc Cutting
Unit 3

Answers to Written Test

1.
a.	3	f.	1
b.	7	g.	6
c.	10	h.	2
d.	5	i.	9
e.	8	j.	4

2.
a. High temperature
b. "Ionized"
c. Constricted
d. No preheating
e. High-velocity

3.
a. 3
b. 4
c. 2
d. 1
e. 5

4. a, b, c, d

5.
a. Decreases
b. High noise levels
c. Nine shade
d. Burn
e. Ventilated
f. Hazardous materials

6.
a. 2
b. 1
c. 1

7. a, b, c, d, e

8. a, b, d, e, f

9.
a. 3
b. 2

10. a, c, d

11.
a. 2
b. 3

Answers to Written Test

12. a, b, c, e, f

13. a. 3
    b. 2
    c. 1

14. a. 2
    b. 2

15. a, b, d

16. a. 2
    b. 2

17. a, b

18. b

19. b, c, d

20. a. 3
    b. 1
    c. 2

21. a, b, c

22. a. Insufficient penetration
    b. Main arc extinguishes
    c. Dross formation

Plasma Arc Cutting
Unit 3

Written Test

Name _____ Score _____

1. Match the terms on the right with their correct definitions.

_____a.	The measurement of flow in an environment where temperature and pressure are not held to a standard	1. Trigger switch
_____b.	Materials or components that are used up during a process	2. Plasma arc
_____c.	A hand cutting technique that requires holding a torch at a slight angle and keeping the torch in contact with the workpiece as a cut is made	3. Cfh
_____d.	A metallic element in PAC electrodes that are used for cutting with air or oxygen	4. Stand-off cutting
_____e.	The measurement of flow in an environment where temperature and pressure are held to standards of temperature and pressure	5. Hafnium
_____f.	The switch or button on a PAC torch that initiates the flow of cutting gas into a plasma arc nozzle	6. Pilot arc
_____g.	The arc initiated *inside* a PAC torch when a cutting gas encounters electrical energy in a nozzle	7. Consumables
_____h.	The arc created *outside* a PAC torch between the nozzle and the workpiece	8. Scfh
_____i.	Control devices that shut off a plasma torch when cutting air falls below a minimum pressure or when torch or machine components overheat	9. Safety interlocks
_____j.	A hand or machine cutting technique in which the plasma torch is held perpendicular to and about ⅛" above the workpiece as the cut is made	10. Contact cutting

2. Complete statements about the basic characteristics of plasma arc cutting. Circle the material that best completes each of the following statements.

   a. The "plasma" in plasma arc cutting is formed when constricted shop air or gas flows through the arc of a (**stainless steel**) (**high temperature**) electrode.

   b. The plasma becomes (**"ionized"**) (**"super heated"**) or electrically conductive and transfers a high temperature electric arc through a nozzle to a workpiece.

   c. When the tip of a plasma arc torch is brought close to or in contact with a workpiece, the plasma stream produces a stiff, (**constricted**) (**gaseous**) cutting arc.

   d. The orifice in the torch nozzle directs the plasma stream to the workpiece where it superheats a small area of the workpiece to a temperature so high that cutting can begin with (**no preheating**) (**minimal preheating**).

   e. As the arc melts the workpiece, the (**high-velocity**) (**high-temperature**) jet blows away molten metal to form the kerf or cut.

3. Match basic components with their functions in an air cut PAC system. Place the number of the component beside its description.

_____a.	A wheel-mounted control cabinet housing electrical components, pressure safety control, electrical overload control, and an air valve assembly	1. Torch lead assembly 2. Filter assembly 3. PAC machine
_____b.	An assembly that contains the pressure regulator for adjusting shop air in p.s.i.	4. Regulator assembly
_____c.	An assembly that filters compressed shop air so that it will be free of oil and water	5. Torch
_____d.	A three-lead cable used to connect the torch to a gas supply, a power source, and a torch trigger interface	
_____e.	A hand-held device which houses the torch head, the electrode, cutting nozzle, shield cup, and trigger switch	

4. Select true statements about plasma arc electrical safety. place an "X" beside each true statement.

   _____a. A plasma arc system must not exceed the amperage ratings of the fuse or breaker of the source power supply.

   _____b. Since system power may vary from 150v to 400v, power leads into a PAC system have to be attached to the correct lugs to avoid erratic performance and possible damage to components.

   _____c. When using an extension cord with a PAC machine, make sure the cord has the proper wire gauge for its length.

   _____d. Always disconnect the power source from the PAC machine before making any internal adjustments or performing troubleshooting.

   _____e. Allow only your hands to come in contact with the workpiece when cutting with a PAC system.

5. Complete statements about plasma arc environmental safety. Circle the material that best completes each of the following statements.

   a. Moisture on human skin (**increases**) (**decreases**) electrical resistance and increases the potential for severe shock, so never use a plasma arc system in damp, wet areas.

   b. Wear ear plugs or muffs for protection when plasma arc cutting because the process produces (**high noise levels**) (**high frequency emissions**).

   c. Infrared/ultraviolet rays produced by the PAC process are hazardous, so always wear an approved filter lens, at least a number (**eight shade**) (**nine shade**) to protect your eyes.

   d. Rays that pose danger to your eyes can also (**burn**) (**irritate**) your skin, and so can molten metal or sparks, so wear gloves, an apron, safety shoes, and safe clothing as the job requires.

   e. Perform PAC in open, well (**lit**) (**ventilated**) areas, and always check confined areas for explosive and toxic gases before cutting starts.

   f. Never cut in an area that contains combustible vapors, flammable liquids, or explosive dust, and NEVER cut into tanks or closed containers that have held (**hazardous materials**) (**cleaning supplies**).

6. Solve problems about plasma arc workplace safety. Circle the number of the statement that best solves each of the following problems.

   a. Plasma arc cutting is taking place next to an old wooden structure. You should:

      (1) Be extra careful.

      (2) Erect a heat shield between the work area and the structure.

      (3) Have someone stand by with a fire extinguisher.

   b. Several small cans of volatile cleaning material are stored fairly close to a position where plasma arc cutting has to be performed. You should:

      (1) Move the cleaning supplies to a safe area.

      (2) Cover the cleaning supplies so sparks can't reach them.

      (3) Erect a barrier of some kind.

   c. You report for a PAC job and find the facility you'll be working in has an old, wooden floor. You should:

      (1) Inform a supervisor that workplaces for plasma arc cutting should have a fireproof floor, and arrange for safe conditions.

      (2) Cover the floor with something safe.

      (3) Go on about PAC cutting, but keep a fire extinguisher handy.

7. Select true statements about advantages of plasma arc cutting. Place an "X" beside each true statement.

   _____a. PAC systems have extremely fast cutting speeds when compared to oxyfuel cutting, or sawing or grinding.

   _____b. Oxyfuel cutting is pretty much confined to carbon steels, but PAC works well with all ferrous and nonferrous metals that are electrically conductive.

   _____c. Because PAC requires no preheating, the cost of fuel gas is minimized and the cutting process is accelerated.

   _____d. No preheating combined with high speed minimize the heat-affected zone and helps control distortion.

   _____e. The cost of fuel gases can be eliminated because PAC can operate with air from a shop air compressor.

   _____f. PAC systems are highly portable and effectively used for indoor maintenance, but seldom used outside.

8. Select true statements about characteristics of plasma arc transfer modes. Place an "X" beside each true statement.

   _____a. The plasma jet formed in a PAC torch can be operated in either the transferred mode or the nontransferred mode.

   _____b. In the nontransferred mode, the electric current first flows between the electrode and the torch nozzle and when the torch strikes or comes close to the workpiece, the arc transfers to the workpiece.

   _____c. In the transferred mode, the least used mode, the electric current flows directly between the electrode and the workpiece when the torch strikes or comes close to the workpiece.

   _____d. Some systems employ a pilot arc to initiate plasma transfer or to restart the arc automatically when electrical contact with the workpiece is interrupted.

   _____e. The pilot arc enables a plasma torch to cut through grating or expanded metal without the operator having to restart the torch time after time, and it also saves wear and tear on consumables.

   _____f. A high frequency pilot arc is used for applications where a torch has to cut through paint, rust, oil, and scale, a condition where the transferred mode could not be initiated.

9. Solve problems about guidelines for PAC electrode selection. Circle the number of the statement that best answers each of the following problems.

   a. You are assigned a plasma arc cutting job which will use compressed air as a cutting gas. You should:

      (1) Use a tungsten electrode because their low cost makes PAC a profitable cutting system.

      (2) Use only a zirconiated electrode.

      (3) Use a hafnium electrode because it will not deteriorate in air as will other types of electrodes.

   b. You are on a PAC job that requires a change of metal thickness from a 1/16" plate to a 1/4" plate. You should:

      (1) Definitely up the amperage on the PAC machine.

      (2) Increase amperage on the PAC machine, but be sure to also change to a recommended electrode.

      (3) Increase amperage and slow the cutting speed to compensate for the thicker metal.

10. Select true statements about guidelines for cutting nozzle selection and installation. place an "X" beside each true statement.

    _____a. Just like electrodes, cutting nozzles are designed for specific amperage ranges; change to the recommended cutting nozzle before changing amperage range.

    _____b. A cutting nozzle is sized according to its length and the size is stamped or laser imprinted on the nozzle.

    _____c. Depending on the manufacturer, the orifice size may be sated in thousandths of an inch for smaller electrodes, fractions of an inch for larger electrodes, or millimeters.

    _____d. Always check the manufacturer's recommended orifice size for the power range, the type and thickness of metal being cut, and the recommended cutting speed.

    _____e. Change or install cutting nozzles with the proper tools, and tighten nozzles until they are really tight.

11. Solve problems about shielding cups, their design and uses. Circle the number of the statement that best solves each of the following problems.

    a. You've been assigned a job that calls for stand-off cutting and have to select a shielding cup. You should:

        (1) Look for a shield cup that has a taper with a smooth face so you can move the torch with ease.

        (2) Look for a shield cup that has a taper with notches in the face to permit gas and fumes to escape while stand-off cutting.

        (3) Select any cup available and simply adjust your cutting speed as required.

    b. You've been asked to explain to a beginning student the difference between contact and stand-off cutting. Aside from explaining the distance required for stand-off cutting, you should:

        (1) Explain the importance of cutting speed when stand-off cutting.

        (2) Note that stand-off cutting is performed with the torch at a 45° angle to the workpiece.

        (3) Note that stand-off cutting is performed with the torch at a 90° angle to the workpiece.

12. Select true statements about plasma air and secondary air used for PAC. Place an "X" beside each true statement.

    _____a. The air that is fed into a PAC torch to be ionized and ejected to form the plasma that cuts through a workpiece is called plasma air or cutting air.

    _____b. The air that is fed into a PAC torch and channeled around the nozzle to provide cooling and help remove metal from the cut is called secondary air or shielding air.

    _____c. In PAC systems that use a coolant, the coolant takes the place of secondary air; the coolant is injected through the torch to help cool components and restrict the arc.

    _____d. Argon is a popular plasma or cutting gas with PAC systems, and is often used in combination with other gases for secondary air; air or oxygen for cutting mild steel, carbon dioxide for cutting stainless steel, and argon/hydrogen for cutting aluminum.

    _____e. The plasma air and the secondary air can be the same, and is in common use with lower amperage PAC systems that use filtered, compressed shop air for both cutting and shielding.

    _____f. Oxygen should not be used as cutting air with a system that has used compressed air unless the compresses air system has been carefully cleaned.

13. Solve problems about PAC consumables, their characteristics and maintenance. Circle the number of the statement that best solves each of the following problems.

    a. You suspect that a cutting problem may be caused by shielding cup wear. To check for cup wear, you should:

        (1) Look for spatter and dross that may have formed on the cup.

        (2) Look for wear along the face of the cup.

        (3) Look for worn, cracked or burned spots that would interfere with performance.

b. You have experienced an erratic arc on a PAC job, and you suspect the trouble is with the cutting nozzle. You should:

(1) Unscrew the nozzle to see if it is stopped up.

(2) Unscrew the nozzle and look for an elongated orifice or an orifice that is obviously oversize.

(3) Take no chances. Simply replace the nozzle.

c. You have placed a new nozzle on a torch. To properly complete the job, you should:

(1) Tighten the nozzle until it is snug, not overtighten.

(2) Tighten the nozzle until it is very tight.

14. Solve problems about PAC system duty cycles. Circle the number of the statement that best solves each of the following problems.

a. You're starting a PAC job that will require a setting of 70 amps. A plate attached to the machine indicates that the duty cycle at 70 amps is 60 percent. This means:

(1) Do not run the machine more than 60 percent of an eight-hour workday.

(2) Do not run the machine more than six minutes out of each ten-minute period.

(3) Run the machine for six minutes straight and then let it cool for six minutes.

b. You're working a PAC system that suddenly overheats and automatically shuts off. You should:

(1) Immediately turn off the supply power and let the machine cool down.

(2) Stop the cutting activity, but leave the machine running so the internal fan can help cool machine components.

(3) Report the machine to a supervisor and find another machine to finish the job.

15. Select true statements about guidelines for setting PAC flow rate and flow pressure. Place an "X" beside each true statement.

    _____a. Flow rate for PAC systems is expressed in Scfh and flow pressure is expressed in p.s.i. or p.s.i.g.

    _____b. Flow rate in Scfh is different from flow rate in cfh in that Scfh references a standard.

    _____c. The important thing to remember about flow pressure is to keep the p.s.i. at exactly 70 p.s.i.

    _____d. Flow pressure in a PAC system may sometimes vary as much as ten pounds plus or minus without affecting equipment, but pressure too high will quickly deteriorate an electrode, and pressure too low will quickly deteriorate a cutting nozzle.

    _____e. All PAC systems have safety interlocks that shut the PAC machine off if flow pressure drops below a minimum point, usually around 20 p.s.i.

16. Solve problems about guidelines for using compressed air with a PAC system. Circle the number of the statement that best solves each of the following problems.

    a. You've been asked to check out a compressed air supply for use with a dual-flow PAC system. You need to:

        (1) Make sure the air supply can reach the PAC system.

        (2) Make sure the air supply is clean, dry, and oil-free.

        (3) Make sure the air supply has high pressure capability.

    b. You've been instructed to set up a PAC system for cutting. For proper set up, you should:

        (1) Make sure the air supply is turned on.

        (2) Drain or air purge the sediment bowl on the air regulator and use the adjusting device to set p.s.i.

        (3) Run plenty of air through the torch to make sure the air is clean and dry.

17. Select true statements about factors affecting cutting speeds. Place an "X" beside each true statement.

    Note: For a statement to be true, all parts of the statement must be true.

    _____a. Several factors affect cutting speeds for PAC, but the most important factors are:

        (1) Power input

        (2) Characteristics of gas flow, both cutting and secondary

        (3) Nozzle design and orifice diameter

        (4) Metal thickness

    _____b. Other factors affecting cutting speeds are the condition of the equipment, the degree of wear on consumable parts, and operator skills.

    _____c. Cutting speeds for mechanized PAC are considerably slower than speeds for hand cutting, but that is because mechanized systems are used for cutting thicker metals.

18. Select true statements about techniques for contact and stand-off cutting. Place an "X" beside each true statement.

    _____a. For normal contact cutting, hold the torch with the arc directed at a slight angle opposite the direction of travel.

    _____b. For stand-off cutting, change to the appropriate shield cup or stand-off device, and direct the arc at a 90° angle straight down at the workpiece.

19. Select true statements about techniques for cutting expanded metal. Place an "X" beside each true statement.

    _____a. With some PAC systems, cutting expanded metal can be a problem because the arc has to be frequently restarted because of the thickness of the metal.

    _____b. To eliminate the problem with restarting the arc, place a thin piece of metal on top of the expanded metal, a straightedge is ideal.

    _____c. Be sure the metal or straightedge is clamped in place so it will not have to be handled during the cutting process.

    _____d. Drag the cutting nozzle along the metal guide, and there should be no problem with having to restart the arc.

20. Solve problems about techniques for gouging metal. Circle the number of the statement that best solves each of the following problems.

    a. When you're setting up for gouging metal, you should:

        (1) Raise the amperage and increase p.s.i.

        (2) Change to a different electrode.

        (3) Change to the recommended electrode and install a gouging nozzle on the torch.

    b. As you're gouging a piece of mild steel, you notice the need for a deeper gouge. You should:

        (1) Increase the torch angle.

        (2) Slow your travel speed.

        (3) Decrease the torch angle.

    c. You're working at the job of removing an inferior weld and notice that you need a wider gouge. You should:

        (1) Stop gouging long enough to change to a different gouging nozzle.

        (2) Weave with the torch to give you a wider gouge.

        (3) Slow your cutting speed and increase amperage.

21. Select true statements about techniques for piercing and beveling metal. Place an "X" beside each true statement.

    _____a. Spray the shield cup with or dip the cup in anti-spatter compound to help minimize spatter and scale that adheres to the cup.

    _____b. Start at a point slightly removed from the cut line and angle the torch slightly to blow particles away from the torch rather than back into the torch.

    _____c. Move from the point that was pierced to the cutting line and finish the cut, and then clean any spatter or scale from the shield cup.

    _____d. To bevel with a PAC system, angle the torch to the desired bevel angle, maintain a 90° angle over the workpiece, and make the cut.

22. Match cutting faults with their probable causes. Insert the name of the problem in the appropriate blank in the following chart.

Problem	Probable Cause
a. _____	Cutting speed too fast Torch tilted too much Metal too thick Worn or damaged torch parts
b. _____	Cutting speed too slow Stand-off too high
c. _____	Improper cutting speed Worn or damaged torch parts

1. Dross formation
2. Insufficient penetration
3. Main arc extinguishes

***Permission to duplicate this test is granted.**

Plasma Arc Cutting
Unit 3

Unit Evaluation Form

Student Name _____ Unit Rating _____

Job Sheet 1—Prepare a PAC Machine for Operation Rating _____

Comments: _____

_____

Job Sheet 2—Complete a Contact Cut on Selected Metal Rating _____

Comments: _____

_____

Job Sheet 3—Complete a Stand-Off Cut on Selected Metal Rating _____

Comments: _____

_____

Job Sheet 4—Gouge Mild Steel Plate With a PAC Unit Rating _____

Comments: _____

_____

Written Test Scores

Pretest _____ Posttest _____ Other _____

Other _____

_____

Teacher Signature _____ Date _____

Student Signature _____ Date _____

***Permission to duplicate this form is granted.**

Plasma Arc Cutting
Unit 3

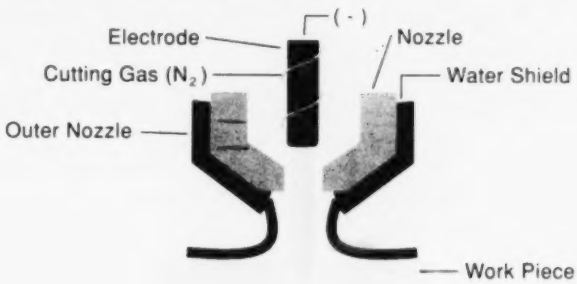
Teacher Supplement 1—Water Cutting With PAC Systems

Introduction

Many mechanized PAC systems use water cutting of one form or another. The early use of water to replace the secondary PAC gas led to improvements in cut quality, but as PAC water systems improved, the results were not only better cut quality, but effective containment of the smoke, fumes, and dangerous ultraviolet rays that are byproducts of the PAC process. The following items briefly present some basics of PAC water cutting that should help students appreciate the rapid improvements in PAC and its permanent place in the skills requirements for welders and cutters.

Water Shield Systems

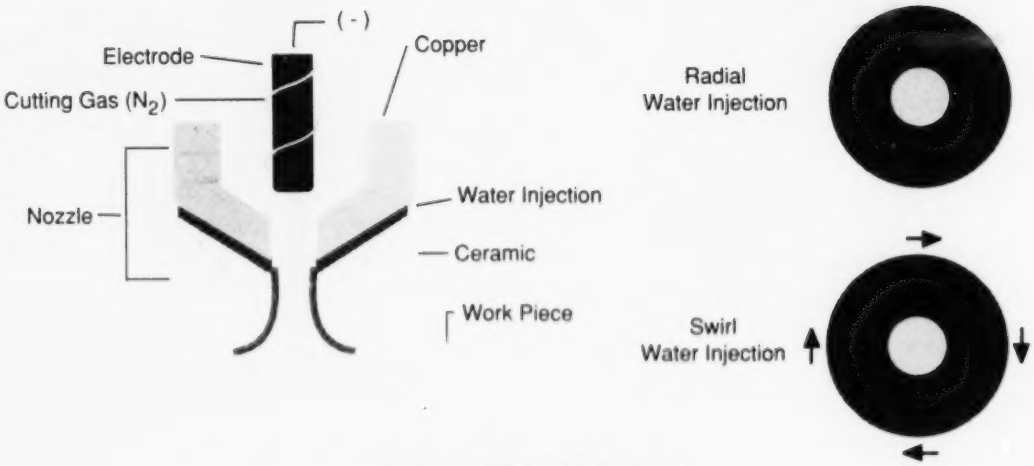
Water shield systems basically replaced the secondary shielding gas with water. The water shield improved cut squareness, but did not provide additional arc restriction required for improved cutting speed and general cut quality.



Courtesy Hypertherm, Inc.

Water Injection Systems

Water injection systems employ either a radial water injection pattern or a swirl water injection pattern. In either case the injection systems not only improved cut squareness, they increased cutting speeds and eliminated dross when cutting mild steel.

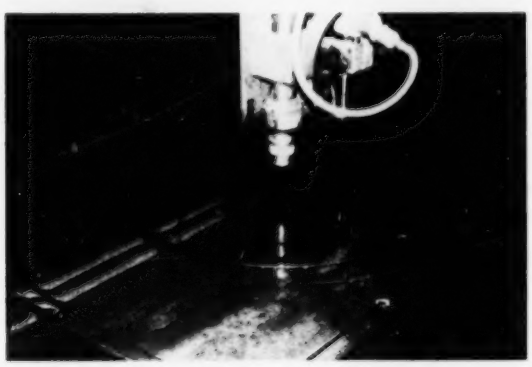


Courtesy Hypertherm, Inc.

Underwater Cutting Systems

In a water table PAC system, the cutting table is filled with water up to the level of the underside of the workpiece, and the cutting nozzle is surrounded with a water shroud.

In an underwater PAC system, the cutting nozzle and the workpiece are submerged in two to three inches of water; when the torch is not cutting underwater, a constant flow of compressed air keeps water out of the torch. Underwater systems have helped eliminate the fumes, smoke, and noise that are part of the PAC process. With special dyes placed in the water, even the ultraviolet rays have been eliminated to improve operator safety.



Courtesy Phelps Fan Co., Little Rock, Arkansas

Plasma Arc Cutting
Unit 3

Information Sheet

1. Terms and definitions

a. **Cfh (Cubic feet per hour)** — The measurement of flow in an environment where temperature and pressure are not held to a standard

b. **Consumables** — Materials or components that are used up during a process

c. **Contact cutting** — A hand cutting technique that requires holding a torch at a slight angle and keeping the torch in contact with the workpiece as a cut is made

d. **Hafnium** — A metallic element in PAC electrodes that are used for cutting with air or oxygen

e. **Pilot arc** — The arc initiated *inside* a PAC torch when a cutting gas encounters electrical energy in a nozzle

f. **Plasma arc** — The arc created *outside* a PAC torch between the nozzle and the workpiece

g. **Safety interlocks** — Control devices that shut off a plasma torch when cutting air falls below a minimum pressure or when torch or machine components overheat

h. **Scfh (standard cubic feet per hour)** — The measurement of flow in an environment where temperature and pressure are held to standards of temperature and pressure

Example: 70°F and pressure at sea level

i. **Stand-off cutting** — A hand or machine cutting technique in which the plasma torch is held perpendicular to and about $\frac{1}{8}$" above the workpiece as the cut is made

j. **Trigger switch** — The switch or button on a PAC torch that initiates the flow of cutting gas into a plasma arc nozzle

2. Basic characteristics of plasma arc cutting

a. The "plasma" in plasma arc cutting is formed when constricted shop air or gas flows through the arc of a high temperature electrode.

b. The plasma becomes "ionized" or electrically conductive and transfers a high temperature electric arc through a nozzle to a workpiece.

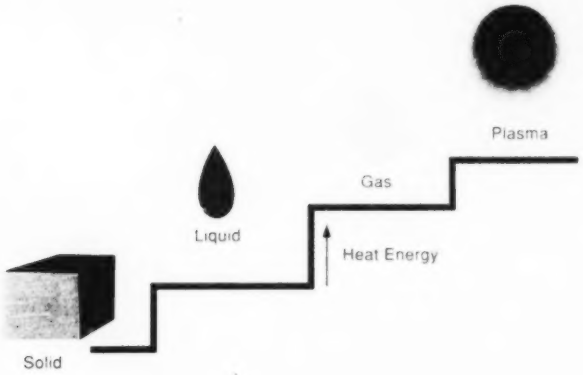
Information Sheet

c. When the tip of a plasma arc torch is brought close to or in contact with a workpiece, the plasma stream produces a stiff, constricted cutting arc.

d. The orifice in the torch nozzle directs the plasma stream to the workpiece where it superheats a small area of the workpiece to a temperature so high that cutting can begin with no preheating.

e. As the arc melts the workpiece, the high-velocity jet blows away molten metal to form the kerf or cut.

Note: Plasma is described as the fourth state of matter. By adding energy to a gas, the temperature and electrical characteristics change through a process called ionization. As ionization takes place, the plasma created becomes electrically conductive and free electrons are available to carry current.



Courtesy Hypertherm, Inc.

3. **Basic components and their functions in an air cut PAC system**

a. **PAC machine** — A wheel-mounted control cabinet housing electrical components, pressure safety control, electrical overload control, and an air valve assembly

b. **Regulator assembly** — An assembly that contains the pressure regulator for adjusting shop air in p.s.i. (pounds per square inch)

c. **Filter assembly** — An assembly that filters compressed shop air so that it will be free of oil and water

d. **Torch lead assembly** — A three-lead cable used to connect the torch to a gas supply, a power source, and a torch trigger interface

e. **Torch** — A hand-held device which houses the torch head, the electrode, cutting nozzle, shield cup, and trigger switch

Information Sheet

4. Plasma arc electrical safety

a. A plasma arc system must not exceed the amperage ratings of the fuse or breaker of the source power supply.

b. Since system power may vary from 150v to 400v, power leads into a PAC system have to be attached to the correct lugs to avoid erratic performance and possible damage to components.

c. When using an extension cord with a PAC machine, make sure the cord has the proper wire gauge for its length.

Note: The longer the extension cord, the lower the wire gauge needs to be.

d. Always disconnect the power source from the PAC machine before making any internal adjustments or performing troubleshooting.

e. Never permit any part of your body to come in contact with the workpiece when cutting with a PAC system.

5. Plasma arc environmental safety

a. Moisture on human skin decreases electrical resistance and increases the potential for severe shock, so never use a plasma arc system in damp, wet areas.

b. Wear ear plugs or muffs for protection when plasma arc cutting because the process produces high noise levels.

c. Infrared/ultraviolet rays produced by the PAC process are hazardous, so always wear an approved filter lens, at least a number nine shade to protect your eyes.

Recommended Eye Protection for Plasma Arc Cutting

Cutting Current Amperes	Lens Shade Number
Up to 300	9
300-400	12
400-800	14

Courtesy American Welding Society

d. Rays that pose danger to your eyes can also burn your skin, and so can molten metal or sparks, so wear gloves, an apron, safety shoes, and safe clothing as the job requires.

e. Perform PAC in open, well ventilated areas, and always check confined areas for explosive and toxic gases before cutting starts.

f. Never cut in an area that contains combustible vapors, flammable liquids, or explosive dust, and NEVER cut into tanks or closed containers that have held hazardous materials.

6. Plasma arc workplace safety

a. A workplace for plasma arc cutting must have a fireproof floor.

b. Work benches used for cutting must have fireproof tops.

c. Erect heat shields or barriers to protect nearby walls and unprotected floor space from flying sparks and hot metal.

d. Combustible materials that can be moved should be moved safely away from the cutting area.

7. Advantages of plasma arc cutting

a. PAC systems have extremely fast cutting speeds when compared to oxyfuel cutting, or sawing or grinding.

b. Oxyfuel cutting is pretty much confined to carbon steels, but PAC works well with all ferrous and nonferrous metals that are electrically conductive.

Note: Electrically conductive nonferrous metals include aluminum, stainless steel, brass, nickel, and copper.

c. Because PAC requires no preheating, the cost of fuel gas is minimized and the cutting process is accelerated.

d. No preheating combined with high speed minimize the heat-affected zone and helps control distortion.

e. The cost of fuel gases can be eliminated because PAC can operate with air from a shop air compressor.

Note: Gases other than air are used in several PAC applications.

f. PAC systems are highly portable and effectively used for everything from indoor maintenance to open-air construction.

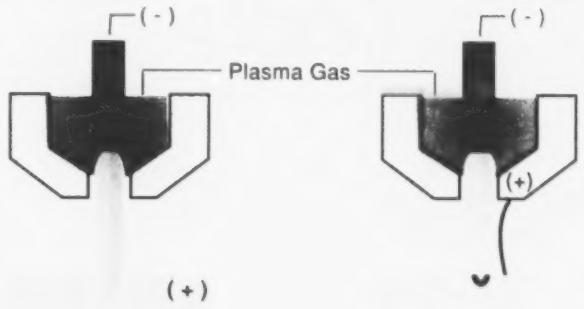
Information Sheet

8. Characteristics of plasma arc transfer modes

a. The plasma jet formed in a PAC torch can be operated in either the transferred mode or the nontransferred mode.

b. In the nontransferred mode, the electric current first flows between the electrode and the torch nozzle and when the torch strikes or comes close to the workpiece, the arc transfers to the workpiece.

c. In the transferred mode, the most commonly used mode, the electric current flows directly between the electrode and the workpiece when the torch strikes or comes close to the workpiece.



Transferred Nontransferred

Courtesy Hypertherm, Inc.

d. Some systems employ a pilot arc to initiate plasma transfer or to restart the arc automatically when electrical contact with the workpiece is interrupted.

e. The pilot arc enables a plasma torch to cut through grating or expanded metal without the operator having to restart the torch time after time, and it also saves wear and tear on consumables.

f. A high frequency pilot arc is used for applications where a torch has to cut through paint, rust, oil, and scale, a condition where the transferred mode could not be initiated.

Note: The high frequency pilot arc is used often in autobody repair where an operator often cuts through paint, rust, or oil.

Information Sheet

9. Guidelines for PAC electrode selection

a. An important factor in selecting an electrode for PAC is the primary or cutting gas that will be used.

b. With PAC systems using nitrogen as a cutting gas, use 2% thoriated or zirconiated electrodes.

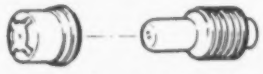
c. Do not use a tungsten electrode for PAC when air or oxygen are used as a cutting gas because tungsten deteriorates rapidly in air or oxygen.

d. Low amperage, dual-flow PAC systems all use a hafnium electrode inserted or embedded in a copper casing because it wears well with air or oxygen as a cutting gas.

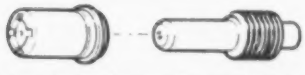
e. The copper casing affords a housing that can be threaded on one end and shaped on the other end so it can be removed or installed with ease, and the copper has excellent electrical characteristics.

f. Hafnium has electrical characteristics that help it absorb ions; this makes it an ideal electrode for ionizing the cutting gas which becomes a plasma.

g. Some PAC systems have extended electrodes designed for cutting in hard-to-reach places like the web of an I-beam or the inside corner of a box; these electrodes require an extended nozzle.



Standard electrode and nozzle



Extended electrode and nozzle

Courtesy Hypertherm, Inc.

Information Sheet

h. Electrodes are rated for use with specific amperage ranges; change to the recommended electrode before changing amperage range.

10. Guidelines for cutting nozzle selection and installation

a. Just like electrodes, cutting nozzles (tips) are designed for specific amperage ranges; change to the recommended cutting nozzle before changing amperage range.

b. A cutting nozzle is sized according to the diameter of it orifice, and the size is stamped or laser imprinted on the nozzle.

c. Depending on the manufacturer, the orifice size may be sated in thousandths of an inch for smaller electrodes, fractions of an inch for larger electrodes, or millimeters.

Orifice Conversion Chart

Inches	Millimeters
.025	1.0
.030	1.2
.035	1.4
.040	1.6
.045	1.8
1/8	3.0
1/4	6.0
3/8	9.0
3/4	18.0
1	25.0

Note: Larger orifices are used for machine cutting on thicker metals.

d. Always check the manufacturer's recommended orifice size for the power range, the type and thickness of metal being cut, and the recommended cutting speed.

e. Change or install cutting nozzles with the proper tools, and tighten nozzles until they are snug, but do not overtighten.

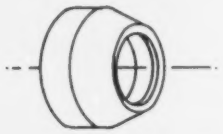
Note: Some PAC systems have nozzles that can be removed and tightened by hand.

Information Sheet

11. Shielding cups, their design and uses

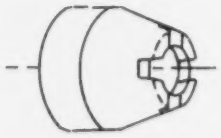
a. Shielding cups protect torch components from damage, confine the secondary gas to help remove metal from the cut, and help cool torch components.

b. For contact cutting, a standard shield cup has a beveled edge that permits the operator to maintain a slight cut angle and to move the torch with ease and accuracy while maintaining contact with the workpiece.



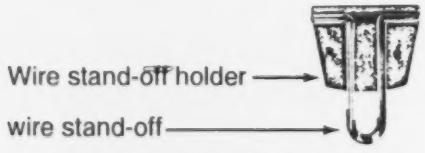
Courtesy Thermal Dynamics Corporation

c. For stand-off cutting, a crown shield cup has an extended bevel edge to provide the required distance for stand-off cutting at a 90° angle; notches in the crown shield permit gases and smoke to escape, and the operator can still rest the shield on the workpiece to improve the ease and accuracy of cutting.



Courtesy Thermal Dynamics Corporation

d. Another device designed for stand-off cutting is a wire stand-off assembly which provides stand-off distance with a wire placed over an unbreakable Teflon® holder.

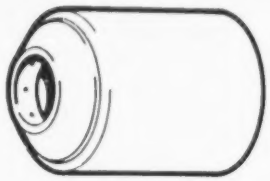


Courtesy Smith Equipment

Information Sheet

e. Another shielding device is a metal retaining cap covered with a high-impact plastic to promote longer consumable life.

Note: The retaining cap is used on PAC systems manufactured by Hypertherm, Inc.



Retaining Cap

Courtesy Hypertherm, Inc.

12. Plasma air and secondary air used for PAC

a. The air that is fed into a PAC torch to be ionized and ejected to form the plasma that cuts through a workpiece is called plasma air or cutting air.

b. The air that is fed into a PAC torch and channeled around the nozzle to provide cooling and help remove metal from the cut is called secondary air or shielding air.

c. In PAC systems that use a coolant, the coolant takes the place of secondary air; the coolant (often water) is injected through the torch to help cool components and restrict the arc.

d. Nitrogen is a popular plasma or cutting gas with PAC systems, and is often used in combination with other gases for secondary air; air or oxygen for cutting mild steel, carbon dioxide for cutting stainless steel, and argon/hydrogen for cutting aluminum.

e. The plasma air and the secondary air can be the same, and is in common use with lower amperage PAC systems that use filtered, compressed shop air for both cutting and shielding.

Note: The job sheets in this unit assume that the student will be working with a PAC system that uses compressed air with a dual-flow torch.

f. Oxygen should not be used as cutting air with a system that has used compressed air unless the compressed air system has been carefully cleaned.

Information Sheet

13. PAC consumables, their characteristics and maintenance

a. With a PAC system, the consumables are usually anything that fits onto or into the plasma torch.

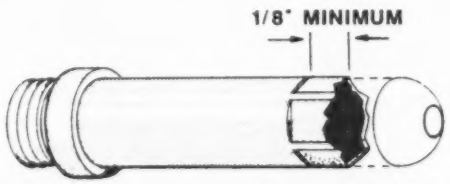
b. Electrodes, cutting nozzles, and shield cups are the items most subject to deterioration.

c. To check for shielding cup wear, look for worn, cracked, or burned areas that would interfere with proper performance, and replace as required.

d. To check for cutting nozzle wear, unscrew the nozzle and look for an elongated or oversize orifice, and replace as required.

e. To check for electrode deterioration, unscrew the electrode and check the condition of the face of the electrode.

f. If less than ⅛" remains on the hex area of the electrode, replace the electrode.



Courtesy Thermal Dynamics Corporation

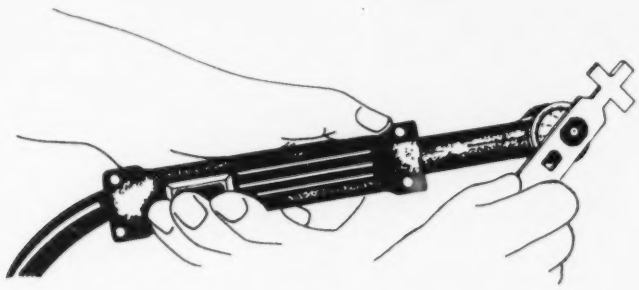
g. Always use the tools shipped with the unit to remove and replace consumables; Thermal Dynamics systems have a wrench to remove nozzles and a nut driver to remove and replace electrodes.

7/32" Nutdriver 7/16" Nozzle Wrench

Courtesy Thermal Dynamics Corporation

Information Sheet

h. Smith Equipment systems have a key safety wrench to remove consumable parts; the wrench is attached to a key so that when the key (and wrench) are extracted from the control panel, power to the torch is shut off to assure operator safety.



Courtesy Smith Equipment

i. Consumables on Hypertherm systems can be removed and retightened by hand; a microswitch in the retaining cap cuts off power to the torch as the cap is removed.

j. A rule of thumb for replacing consumables is to tighten components until they are snug; never overtighten.

14. PAC system duty cycles

a. As with other welding machines, PAC systems have duty cycle ratings which specify the amount of time a given load may be applied to a power source without overheating the internal components.

b. The duty cycle reference period for all welding machines is a ten minute interval.

Example: If a 40/80 unit is rated at 100% duty cycle for the 40 amp output setting, the power source can supply a 40 amp output load for 100% of the time. In other words, it can run continuously with the use of an internal fan, it does not have to be shut down to cool. On the other hand, if the 80 amp output of the unit had a 60% duty cycle, it should be used for only six minutes and then allowed to cool for four minutes.

c. When a duty cycle is exceeded, thermal sensors in the unit shut off power to automatically protect components, and the shutdown is indicated by an illuminated fault light on the control panel.

d. When a system shuts down after exceeding the duty cycle, don't panic and unplug the source power, instead, leave power on so the fan will continue to run and cool the system.

Information Sheet

15. Guidelines for setting PAC flow rate and flow pressure

a. Flow rate for PAC systems is expressed in Scfh (standard cubic feet per hour) and flow pressure is expressed in p.s.i. (pounds per square inch) or p.s.i.g. (pounds per square inch gauge).

b. Flow rate in Scfh is different from flow rate in cfh in that Scfh references a standard.

Example: A supply of compressed air at 70 p.s.i. should provide pressure enough to make the air flow at a rate of 270 Scfh.

c. The important thing to remember about flow pressure is to keep the p.s.i. at the pressure recommended by the equipment manufacturer.

d. Flow pressure in a PAC system may sometimes vary as much as ten pounds plus or minus without affecting the equipment, but pressure too high will quickly deteriorate an electrode, and pressure too low will quickly deteriorate a cutting nozzle.

e. All PAC systems have safety interlocks that shut the PAC machine off if flow pressure drops below a minimum point, usually around 40 p.s.i.

16. Guidelines for using compressed air with a PAC system

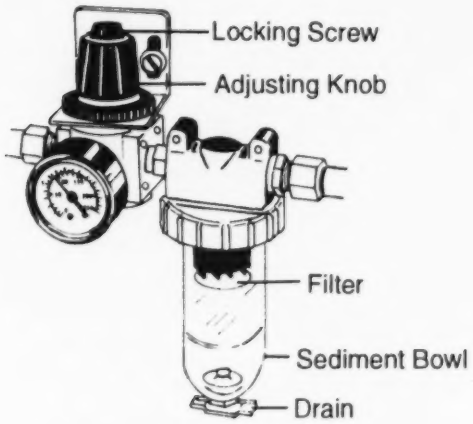
a. When compressed air is used with a PAC system, the air must be clean, dry, and oil-free.

b. Many dual-flow PAC systems have air regulators attached to the machine, but in cases where air quality may be in question, it is wise to install an in-line filter between the air supply source and the regulator.

Typical in-line filter made of pipe. The length of the extension between the top quick-connect fitting and the bottom drain permits oil and water to settle and be vented through the bottom drain valve.

Information Sheet

c. Regulator assemblies have an adjusting device to set p.s.i. and a filter with a sediment bowl that has a screw-type or pressure drain.



Courtesy Smith Equipment

d. Since the sediment bowl collects water, oil, and other matter, it must be drained or pressure purged each time the system is set up for cutting.

17. Factors affecting cutting speeds

a. Several factors affect cutting speeds for PAC, but the most important factors are:

(1) Power input

(2) Characteristics of gas flow, both cutting and secondary

(3) Nozzle design and orifice diameter

(4) Metal thickness

Information Sheet

b. Other factors affecting cutting speeds are the condition of the equipment, the degree of wear on consumable parts, and operator skills.

Note: The following chart shows suggested cutting speeds for mild steel. The medium range, 40 amps, is typical for PAC systems. Travel speeds for cutting aluminum are slower than for mild steel, and speeds for cutting stainless are even slower.

MATERIAL	THICKNESS		CURRENT	APPROXIMATE TRAVEL SPEED	
	(inches)	(mm)	(Amps)	(IPM)	(mm/min)
MILD STEEL	28 GA	0.4	40	450	11400
	24 GA	0.6	40	350	8900
	18 GA	1.2	40	225	5700
	1/16	1.5	40	180	4600
	1/8	3	40	100	2500
	1/4	6	40	35	890
	3/8	9.5	40	15	380
	1/2	12	40	10	250

Courtesy Hypertherm, Inc.

c. Cutting speeds for mechanized PAC are considerably faster than speeds for hand cutting, and mechanized systems typically handle thicker metals.

Note: The following AWS chart displays typical conditions for mechanized cutting of carbon steel.

Thickness		Speed		Orifice Diam*			
in.	mm	in./min	mm/s	in.	mm	Current (dcsp), A	Power kW
1/4	6	200	86	1/8	3.2	275	55
1/2	13	100	42	1/8	3.2	275	55
1	25	50	21	5/32	4.0	425	85
2	51	25	11	3/16	4.8	550	110

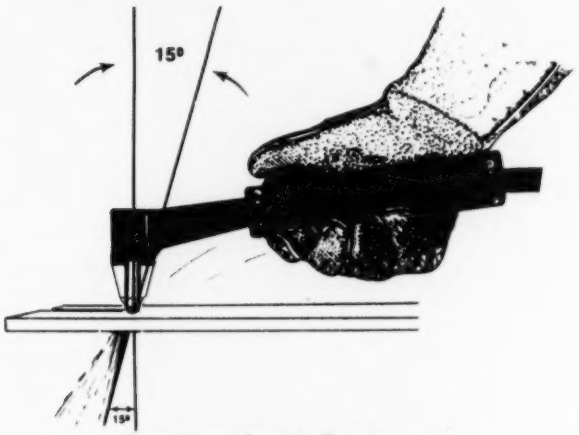
*Plasma gas flow rates vary with orifice diameter and gas used from about 200 ft^3/h (94 L/min.) for a 1/8 in. (3.2 mm) orifice to about 300 ft^3/h (104 L/min.) for a 3/16 in. (4.8 mm) orifice. The gases used are usually compressed air, nitrogen with up to 10% hydrogen additions, or nitrogen with oxygen added downstream from the electrode (dual flow). The equipment manufacturer should be consulted for each application.

Courtesy American Welding Society

Information Sheet

18. Techniques for contact and stand-off cutting

a. For normal contact cutting, hold the torch with the arc directed at a slight angle in the same direction of travel.



Courtesy Smith Equipment

b. For stand-off cutting, change to the appropriate shield cup or stand-off device, and direct the arc at a 90° angle straight down at the workpiece.

19. Techniques for cutting expanded metal

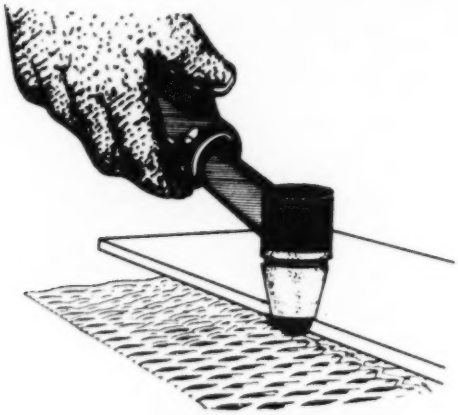
a. With some PAC systems, cutting expanded metal can be a problem because the arc has to be frequently restarted because of the open spaces that will not maintain electrical continuity.

b. To eliminate the problem with restarting the arc, place a thin piece of metal on top of the expanded metal, a straightedge is ideal.

c. Be sure the metal or straightedge is clamped in place so it will not have to be handled during the cutting process.

Information Sheet

d. Drag the cutting nozzle along the metal guide, and there should be no problem with having to restart the arc.

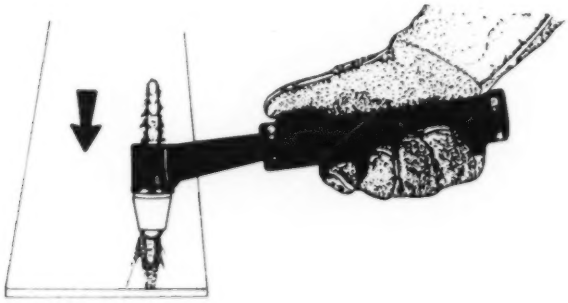


Courtesy Smith Equipment

20. Techniques for gouging metal

a. Turn the power off, install the recommended electrode, and install a gouging nozzle on the torch so you will have a wider arc.

b. Start the arc by briefly dragging the torch across the metal surface, and immediately angle the torch at a gouging angle and push it across the surface.



Courtesy Smith Equipment

c. To make a shallow gouge, lessen the torch angle; to make a deeper gouge, increase the torch angle.

d. Do not attempt to remove too much metal in a single pass; repeat gouging if more metal needs to be removed.

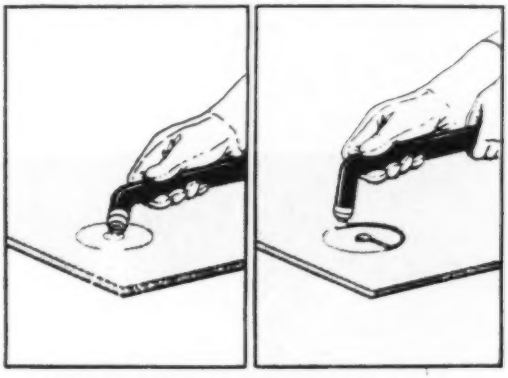
> **Caution: Metal gouging increases wear on consumables, and steep gouging angles could cause heat and slag to blow back into the nozzle and damage it.**

e. When preparing a crack for repair or removing an inferior weld, make a wider gouge by weaving the torch.

21. Techniques for piercing and beveling

a. Spray the shield cup with or dip the cup in anti-spatter compound to help minimize spatter and scale that adheres to the cup.

b. Start at a point slightly removed from the cut line and angle the torch slightly to blow particles away from the torch rather than back into the torch.



Courtesy Thermal Dynamics, Inc.

c. Move from the point that was pierced to the cutting line and finish the cut, and then clean any spatter or scale from the shield cup.

d. To bevel with a PAC system, angle the torch to the desired bevel angle, maintain a slight angle opposite the direction of travel, and make the cut.

Information Sheet

22. Common cutting faults and their probable causes

Problem	Probable Cause
Insufficient penetration	Cutting speed too fast Torch tilted too much Metal too thick Worn or damaged torch parts
Main arc extinguishes	Cutting speed too slow Stand-off too high
Dross formation	Improper cutting speed Worn or damaged torch parts

Plasma Arc Cutting
Unit 3

Job Sheet 1—Prepare a PAC Machine for Operation

Name _____ Attempt Number _____

Date _____ Overall Rating _____

Evaluation criteria	Rating
Compressed air supply purge	_____
Air pressure verification	_____
Set up and shut down safety	_____

A. Tools and materials

PAC machine with torch and accessories
Operator's manual for selected PAC machine
Personal safety clothing and safety glasses

B. Procedure

☐ 1. Check the workplace for flammable materials, and remove or cover them.

☐ 2. Turn on the compressed air supply.

☐ 3. Locate the compressed air filter on the air line between the air supply and the PAC machine.

☐ 4. Purge excess moisture from the filter by depressing the purge button at the bottom of the filter.

Note: If you're working with a system that has a different type of filter, check the operator's manual for the correct procedure, and if you have to replace a filter, be sure the compressed air supply is turned off.

☐ 5. Turn on the PAC machine power switch.

☐ 6. Set air pressure to manufacturer's specifications.

☐ 7. Press the trigger button on the plasma torch and listen for air flow through the torch.

Job Sheet 1

- ☐ 8. Watch the air pressure as you press the trigger button; there should be a slight drop in pressure to indicate proper air flow.
- ☐ 9. Have your instructor check your work.
- ☐ 10. Turn the power switch off.
- ☐ 11. Secure the PAC machine and the plasma torch.

Evaluator's comments: _____

_____

_____

Plasma Arc Cutting
Unit 3

Job Sheet 2—Complete a Contact Cut on Selected Metal

Name _____ Attempt Number _____

Date _____ Overall Rating _____

Evaluation criteria	Rating
Workpiece preparation	_____
Workpiece cut alignment	_____
Use of straightedge and clamps	_____
Setup technique	_____
Ground clamp placement	_____
Proper angle to start cut	_____
Cutting technique	_____
Shutdown technique	_____

A. Tools and materials

PAC machine with torch and accessories
Welding helmet or goggles with minimum #9 lens shade
Metal as selected by instructor
Contact shielding cup for plasma torch
Straightedge, soapstone, and C clamps
Wire brush
Ear protection, safety clothing, and safety glasses

B. Procedure

☐ 1. Check the workplace for flammable materials, and remove or cover them.

☐ 2. Put on safety glasses.

☐ 3. Clean all rust and scale from the workpiece with a wire brush.

Job Sheet 2

- ☐ 4. Measure and mark the cutting line on the workpiece with a straightedge and soapstone.
- ☐ 5. Place the workpiece on the work table with the edge to be cut extended over the edge of the table, far enough for the plasma stream to clear the work table.
- ☐ 6. Place the straightedge along the cut line and clamp the straightedge and the workpiece to the work table with the clamps positioned so they will not interfere with the cut.
- ☐ 7. Clamp the PAC machine ground clamp onto the workpiece or as close to the workpiece as possible.
- ☐ 8. Set up the PAC machine as previously outlined.
- ☐ 9. Turn the PAC power switch on; put on your welding goggles or helmet and ear protection.
- ☐ 10. Position the contact shielding cup so that it contacts the workpiece at a slight angle opposite the direction of travel.
- ☐ 11. Press the torch trigger button; listen for air flow to start through the plasma torch.
- ☐ 12. Wait about two seconds for the pilot arc to come on, and immediately move the torch along the cut line.
- ☐ 13. Use a smooth, continuous motion to move the plasma torch along the straightedge while maintaining the correct torch angle all along the cut.

> **Caution: Keep your legs and feet out of the way as you finish the cut because the cut portion will fall off.**

- ☐ 14. Complete the cut, release the gun trigger button, and keep the torch in your hand as the arc stops and air continues to flow.
- ☐ 15. Allow air to flow until it stops to help cool gun components.
- ☐ 16. Have your instructor check your work.
- ☐ 17. Turn the power switch off.

Job Sheet 2

☐ 18. Secure the PAC machine and torch.

☐ 19. Clean the area and return tools and materials to proper storage.

Evaluator's comments: _____

_____

_____

Plasma Arc Cutting
Unit 3

Job Sheet 3—Complete a Stand-Off Cut on Selected Metal

Name _____ Attempt Number _____

Date _____ Overall Rating _____

Evaluation criteria	Rating
Workpiece preparation	_____
Cutting line mark	_____
Shield cup selection	_____
Setup technique	_____
Ground clamp placement	_____
Torch angle	_____
Cutting technique	_____
Shutdown technique	_____

A. Tools and materials

PAC machine with torch and accessories
Welding helmet or goggles with minimum #9 lens shade
Metal as selected by instructor
Stand-off shielding cup or device for plasma torch
Straightedge, soapstone, and C clamps
Wire brush
Ear protection, safety clothing, and safety glasses

B. Procedure

☐ 1. Check the workplace for flammable materials, and remove or cover them.

☐ 2. Put on safety glasses.

☐ 3. Clean all rust and scale from the workpiece with a wire brush.

Job Sheet 3

- ☐ 4. Measure and mark the cutting line on the workpiece with a straightedge and soapstone.
- ☐ 5. Place the workpiece on the work table with the edge to be cut off extended over the edge of the table, far enough for the plasma stream to clear the work table.
- ☐ 6. Secure the workpiece with C clamps.
- ☐ 7. Clamp the PAC machine ground clamp on the workpiece or as close to the workpiece as possible.
- ☐ 8. Set up the PAC machine as previously outlined.
- ☐ 9. Use the proper tool to remove the standard shield cup, and replace it with a stand-off shield cup or stand-off device.

  Note: Tighten the cup until it is snug. Don't overtighten. If you're working with a system that recommends hand tightening, don't use a tool.
- ☐ 10. Position the plasma torch so that it touches the workpiece and is aligned vertically at a 90° angle with the workpiece.
- ☐ 11. Maintain the 90° angle while you press the torch trigger switch; listen for air flow to start through the plasma torch.
- ☐ 12. Wait for about two seconds for the pilot arc to come on, and immediately move the torch along the cut line.
- ☐ 13. Use a smooth, continuous motion to move the plasma torch along the cut line while maintaining the 90° torch angle all along the cut line.
- ☐ 14. Complete the cut, release the trigger switch, and keep the torch in your hand as the arc stops and air continues to flow.
- ☐ 15. Allow air to flow until it stops; this helps cool torch components.
- ☐ 16. Have your instructor check your work.
- ☐ 17. Turn off the power switch.
- ☐ 18. Secure the PAC machine and torch.
- ☐ 19. Clean the area and return tools and materials to proper storage.

Evaluator's comments: _____

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Plasma Arc Cutting
Unit 3

Job Sheet 4—Gouge Mild Steel Plate With a PAC Unit

Name _____ Attempt Number _____

Date _____ Overall Rating _____

Evaluation criteria	Rating
Workpiece preparation	
Gouging line mark	
Gouging cup selection	
Setup technique	
Ground clamp placement	
Gouging angle and technique	
Shutdown technique	

A. Tools and materials

PAC machine with torch and accessories
Welding helmet or goggles with minimum #9 lens shade
Metal as selected by instructor
Gouging nozzle for plasma torch
Straightedge, soapstone, and C clamps
Wire brush
Ear protection, safety clothing, and safety glasses

B. Procedure

☐ 1. Check the workplace for flammable materials, and remove or cover them.

☐ 2. Put on safety glasses.

☐ 3. Clean all rust and scale from the workpiece with a wire brush.

Job Sheet 4

- ☐ 4. Measure and mark the gouging line on the workpiece with a straightedge and soapstone.
- ☐ 5. Place the workpiece on the work table so that sparks from gouging will blow into a safe area.
- ☐ 6. Secure the workpiece with C clamps.
- ☐ 7. Clamp the PAC machine ground clamp on the workpiece or as close to the workpiece as possible.
- ☐ 8. Set up the PAC machine as previously outlined.
- ☐ 9. Use the proper tools to remove the shield cup and nozzle, and repiace the nozzle with a gouging nozzle.

  Note: Tighten the cup until it is snug. Don't overtighten. If you're working with a system that recommends hand tightening, don't use a tool.
- ☐ 10. Position the shield cup so that it contacts the workpiece at an angle approximately 30° from the horizontal.
- ☐ 11. Press the torch trigger switch while you listen for air flow to start through the plasma torch.
- ☐ 12. Wait for about two seconds for the pilot arc to come on, and immediately move the torch along the gouge line.
- ☐ 13. Use a smooth, continuous motion to push the torch along the gouge line; you may need to adjust the torch angle up slightly for a deeper gouge or adjust the angle down slightly for a more shallow gouge, or adjust travel speed.
- ☐ 14. Complete the gouge, release the trigger switch, and keep the torch in your hand as the arc stops and air continues to flow.
- ☐ 15. Allow air to flow until it stops; this helps cool torch components.
- ☐ 16. Have your instructor check your work.

  Note: Your instructor may instruct you to experiment with torch angles and travel speed. The instructor may also instruct you to experiment with a weaving technique to broaden the width of the gouge.
- ☐ 17. Turn off the power switch.

Job Sheet 4

☐ 18. Secure the PAC machine and torch.

☐ 19. Clean the area and return tools and materials to proper storage.

Evaluator's comments: _____

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